Chapter 10. Viewing, Reporting and Ground Truthing the Results

10.1 Guidance for Reporting Loss Results

There is no single format that is appropriate for presentation of loss study results. The format will depend on the use of the results and the intended audience. The audience can vary from the general public to technical experts. Decision makers such as city council members and other government officials may require only summaries of losses for a region. Emergency response planners may want to see the geographical distribution of all losses and damage for several different earthquake scenarios. **HAZUS** provides a great deal of flexibility in presenting results. Results can be presented in a tabular or map form - which maps or tables are selected for reports will depend on the application. In any case, the users of the results should be involved from the beginning in determining the types and formats of the results that best suit their needs.

In previous loss studies, authors of reports have had the difficult task of trying to combine the study results with the theory of how they were calculated. Consequently, reports often seemed overly technical, reducing their readability and usefulness for many audiences. **HAZUS** users can refer to the *Technical Manual* that describes all of the theories and equations that provide the basis of any loss estimate. Thus reports do not need to, and probably should not, include technical discussions of theory. Instead, reports should focus on describing results in non-technical language that is easily understood by the intended audience.

While no particular format for presenting results can be recommended, several general statements about reporting of results can be made. Reports should serve to clarify the meaning of the loss estimates. As an example, the reporting of economic loss should indicate whether both direct and indirect losses are included in the estimates. The report should indicate whether losses are due only to structural and non-structural damage or if they also include monetary losses resulting from loss of function. Casualty reports should indicate that casualties include only those that result from building damage and bridge collapse and do not include injuries and deaths from fires, flood, hazardous material releases or medical causes such as heart attacks. It should be clarified that in most cases losses are not calculated for specific buildings or facilities, but instead are based on the performances of entire classes of buildings and lifelines. These are just a few examples of the types of clarifications that should appear in reports.

Reports should also clarify for the reader what assumptions were made in developing the scenario and inventory and in calculating losses. For example, were losses based on default inventories or were default inventories augmented? Were default repair costs and repair times used? If not, what values were used? Were soils maps provided or were results based on a default soil type? What assumptions were made in selecting the scenario earthquake? Is it based on an historical event? Is it based on a specified probability of occurrence (e.g. 10% chance in 200 years)? What types of assumptions were made about design and construction quality?

A criticism of past studies is that there has been little qualitative or quantitative treatment of uncertainty. Discussions with users of previous studies have indicated that users need information about where errors in prediction are most likely to occur. While this methodology does not explicitly include a technique for carrying the uncertainty of each variable through the entire calculation from PESH input to loss estimates, sensitivity analyses are useful for providing bounds on loss estimates (see Section 9.8). At a minimum, reports should make some statement about the uncertainty of the input values.

10.2 Module Outputs

Each of the modules of **HAZUS** provides the user with a series of outputs. The outputs can be in a numerical or graphical form. Some of the modules yield intermediate results that are used as inputs to other modules. For example, the PESH module determines ground motion at different locations for a specified earthquake scenario. This information by itself may not be very useful for hazard mitigation and emergency planning. However, the results of the PESH module are used as an input to determine the damage to structures in the Direct Physical Damage module. In the following sections, summaries of the outputs of the modules are provided.

10.3 Potential Earth Science Hazards

HAZUS provides information about the expected ground shaking response for a specified event in the given study region. The user may specify a deterministic scenario event. For the purposes of emergency response and preparedness, a scenario event is commonly used to estimate earthquake consequences and losses. The user can also opt for a pseudo-probabilistic approach that can be used to compute expected annual losses. This type of approach may be useful for comparing mitigation strategies. Finally the user can use an existing ground motion map prepared by an expert.

Table 10.1 summarizes the module outputs for these three options. In all three cases, the user is provided with ground shaking in the study region characterized in terms of peak ground acceleration (PGA) and spectral accelerations (5% damping) at two specific structural periods (0.3 and 1.0 seconds).

Table 10.1 PESH Module Outputs - Ground Motion/Site Effects

Component	Description of Output	Measure
Deterministic Event	**HAZUS** determines census tract ground motion and develops region-wide ground motion contour maps based on a user-defined scenario event.	a) Census Tract Ground Shaking b) PGA Contour Maps c) Spectral Contour Maps
USGS Probabilistic Seismic Hazard Maps	**HAZUS** includes spectral contour maps at two seismic hazard levels: 2% probability of exceedance in 50 years and 10% probability of exceedance in 50 years	a) PGA Contour Maps b) Spectral Contour Maps
User-Supplied Ground Shaking Maps	The user supplies region-wide ground motion contour maps which are used as the ground motion inputs to **HAZUS**	a) Census Tract Ground Shaking b) PGA Contour Maps c) Spectral Contour Maps

For identified susceptible areas, **HAZUS** provides information concerning the probability of an expected level of permanent ground deformations (PGD) due to the specified scenario event. In this methodology, permanent ground deformation is defined as liquefaction, landsliding and surface fault rupture. PGD are important in estimating losses to and functionality of lifelines. Table 10.2 summarizes the ground deformation outputs of the PESH module. PGD are reported in terms of contour maps of ground deformations (in meters) or site specific PGD.

Table 10.2 PESH Module Outputs - Ground Deformation

Component	Description of Output	Measure
Liquefaction	**HAZUS** determines the probability of and expected level of permanent ground deformations for liquefaction susceptible sites during the deterministic, probabilistic, or user-defined event.	a) PGD Contour Maps b) Location-Specific PGD
Landsliding	**HAZUS** determines the probability of and expected level of permanent ground deformations for landsliding susceptible sites during the deterministic, probabilistic, or user-defined event.	a) PGD Contour Maps b) Location-Specific PGD
Surface Fault Rupture	**HAZUS** determines the probability of and expected level of permanent ground deformations for surface fault rupture susceptible sites during the deterministic, probabilistic, or user-defined event.	a) PGD Contour Maps b) Location-Specific PGD

Outputs of the PESH module can be accessed from the **Results|Ground Motion** menu (See Figure 10.1). Ground motion maps can be viewed in two forms: census tract-based or contour maps. To generate census tract-based maps, HAZUS evaluates the ground motion at the census tract centroid and then assigns the value to the census tract. The census tract- based information is used to derive the damage and loss estimates for the general building stock. Contour maps that are generated by **HAZUS** are for display purposes only. Contour maps that are digitized and entered by the user can be used for further computations. From the **Ground Motion or Failure** menu (see Figure 10.1), you can plot a variety of maps by choosing one of the options**: Ground Motion (By Census Tracts)** or **Contours or Ground Failure Maps**. For the **Ground Motion (By Census Tracts)** option, as shown in Figure 10.2, you can generate acceleration, displacement, velocity, PGV or PGA maps by clicking on the appropriate column of data and then clicking on the **Map** button. Examples of these maps are found in Figures 10.3 and 10.4. For the **Contours or Ground Failure Maps** option, you may plot any of the parameters shown in Figure 10.5 provided that you have already run the specific analysis that you want to plot. Click on your choice in Figure 10.5, followed by the **Map** button.

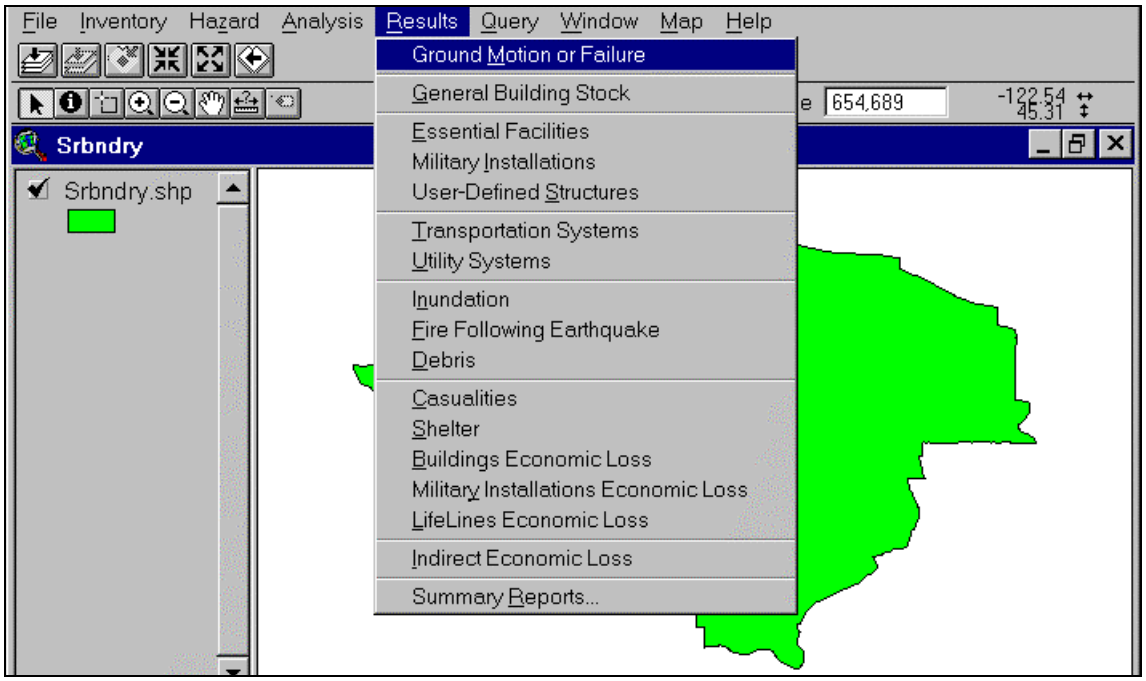
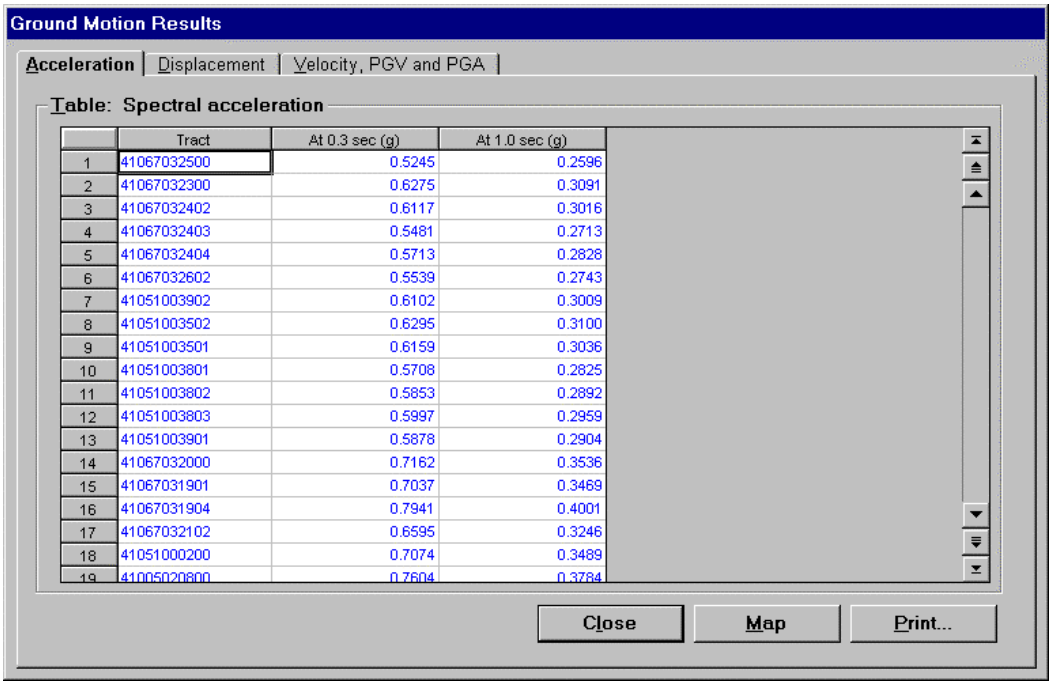


Figure 10.1 Accessing PESH module results.



	Tract	At 0.3 sec (g)	At 1.0 sec (g)
1	41067032500	0.5245	0.2596
2	41067032300	0.6275	0.3091
3	41067032402	0.6117	0.3016
4	41067032403	0.5481	0.2713
5	41067032404	0.5713	0.2828
6	41067032602	0.5539	0.2743
7	41051003902	0.6102	0.3009
8	41051003502	0.6295	0.3100
9	41051003501	0.6159	0.3036
10	41051003801	0.5708	0.2825
11	41051003802	0.5853	0.2892
12	41051003803	0.5997	0.2959
13	41051003901	0.5878	0.2904
14	41067032000	0.7162	0.3536
15	41067031901	0.7037	0.3469
16	41067031904	0.7941	0.4001
17	41067032102	0.6595	0.3246
18	41051000200	0.7074	0.3489
19	41005020800	0.7604	0.3784

Figure 10.2 Selecting site-specific data generated in the PESH module

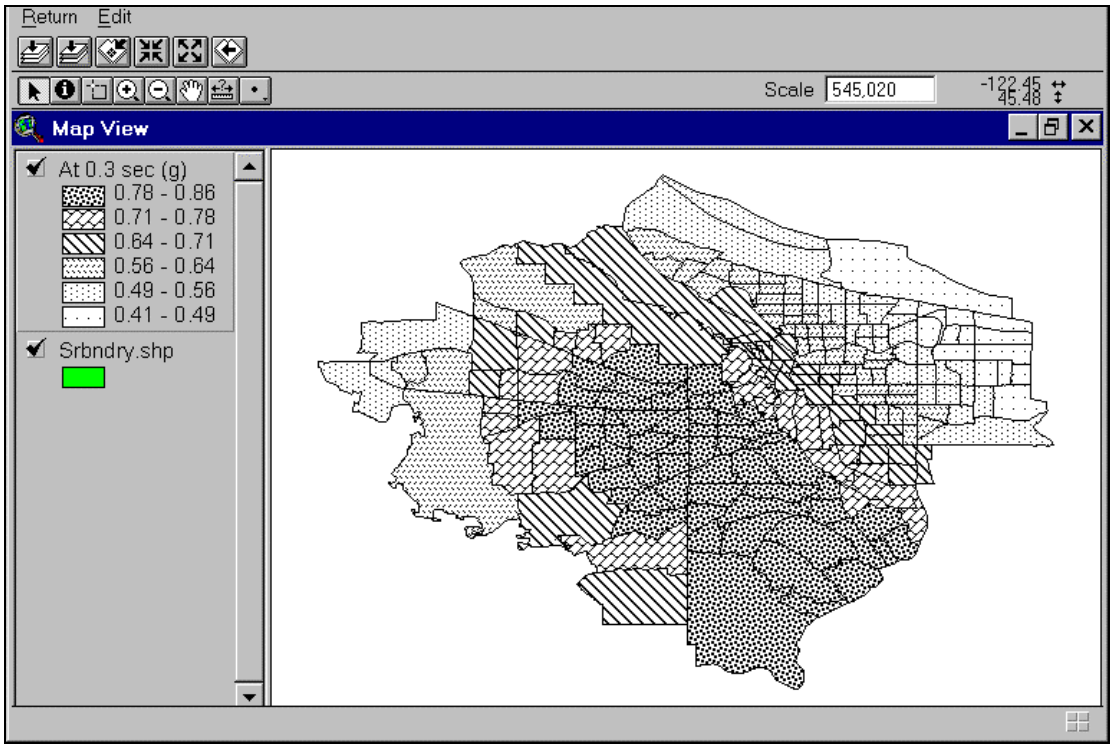


Figure 10.3 Map of 0.3 second spectral acceleration by census tract

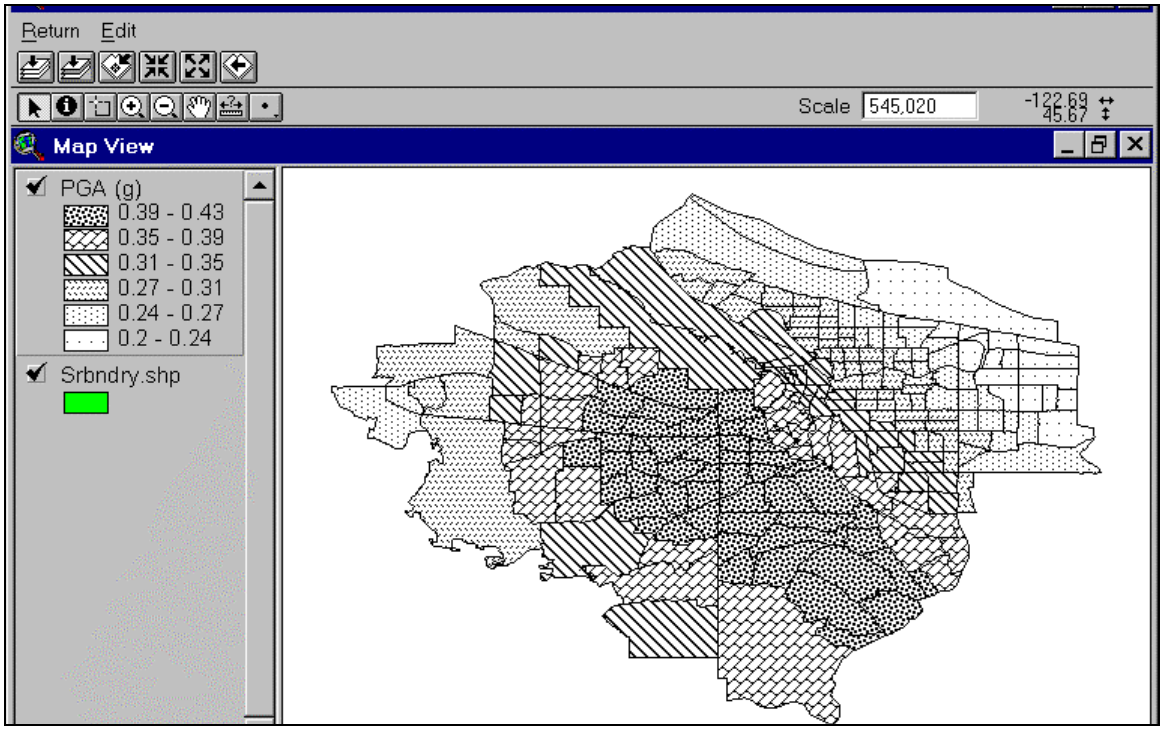


Figure 10.4 Map of peak ground acceleration by census tract.

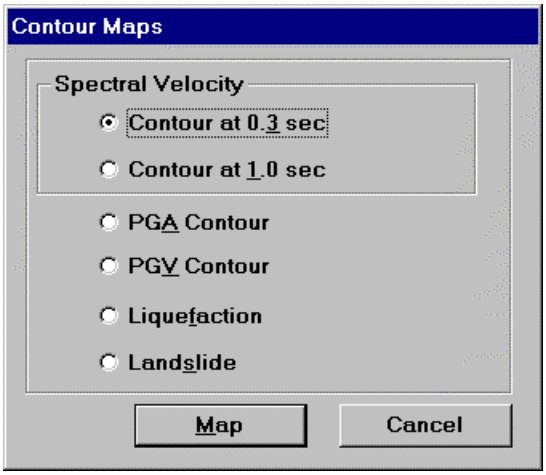


Figure 10.5 Window to select PESH contours for mapping.

10.3.1 Ground Motion Descriptions

Many of the earlier regional loss estimation studies and methods have based losses on MMI and isoseismal maps (maps showing areas of constant MMI). In **HAZUS**, PGA, PGV and SA characterize ground shaking. The use of spectral acceleration allows **HAZUS** to account for possible amplification of building motion and consequently damage due to sympathetic response of a building to the earthquake motions. Sympathetic response of a building (or amplification of building shaking) is similar to what you experience when on a swing. If you pump your legs at a certain frequency, the swing will go very high and very fast. If the ground motion shakes the building at a certain frequency the building will experience amplification of its motions. Fast shaking excites short buildings and slower shaking excites tall buildings. Presenting ground motion in terms of spectral velocity and spectral acceleration gives information about the frequency of the ground shaking. This in turn can be used to determine which buildings (tall or short) are most excited and thus most damaged by a particular earthquake.

10.4 Direct Physical Damage - General Building Stock

The direct physical damage module of **HAZUS** provides information about the level of damage to the study region's general building stock. Damage to the general building stock is not evaluated on a building-by-building basis. Instead, damage is estimated and reported for groups of buildings in each census tract. Damage to the general building stock is defined in terms of the probability that a specific model building type will reach or exceed a specified level of damage when subjected to a given level of ground motion. Damage estimates are then converted in other modules into monetary losses and social losses such as casualties and shelter demands (see, for example, Figure 10.6).

Losses such as the costs of reconstruction, the length of business interruption, the number of people needing shelter and the severity of injuries and number of casualties all depend on the severity of the damage. While estimation of social and economic losses is the ultimate goal of a loss study, some knowledge of the geographical distribution of damage may be helpful in planning for post-earthquake response or in determining strategies for mitigation, for example, if the scenario identifies a particular area where a large number

of buildings are likely to collapse, planning for rescue efforts in this area may be important.

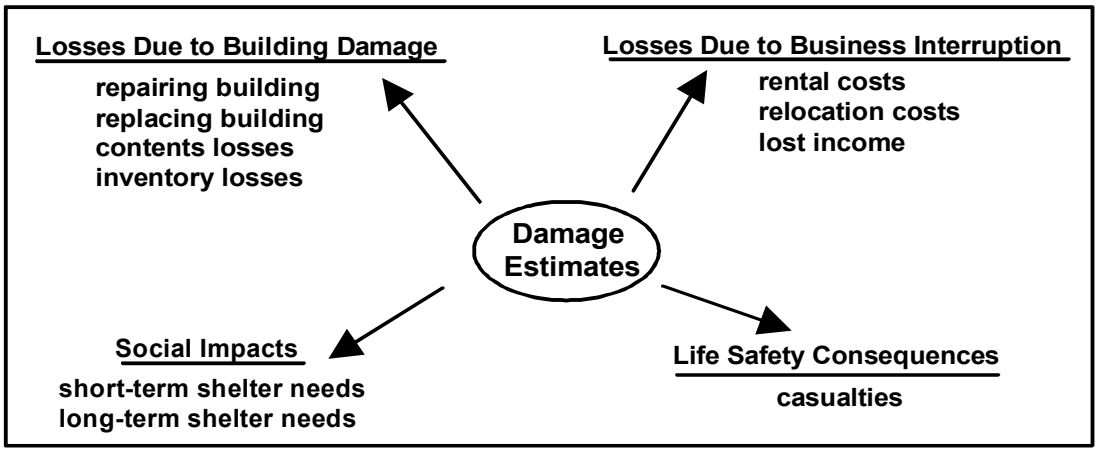


Figure 10.6 Losses calculated from damage estimates.

Damage is described by five damage states (none, slight, moderate, extensive and complete) that are defined in detail in Section 9.4.2. Estimates of earthquake damage are provided in terms of damage state probabilities or building count. For a specified earthquake, the user is provided with the probability of a structural type experiencing a certain level of damage. For example, for a given earthquake, wood frame structures may have a probability of 0.9 of experiencing no damage and a probability of 0.1 of experiencing slight damage. As shown in Table 10.3, damage state probabilities are provided for structural as well as non-structural damage, where as building counts are only provided for structural damage. To provide the most flexibility to the user, the module delivers damage state probabilities for model building types, specific occupancy classes and general occupancy classes. Results are available in a tabular or map format.

Table 10.3 Direct Physical Damage Module Outputs - General Building Stock

Component	Description of Output	Measure
Model Building Type	**HAZUS** determines the damage state probability for each model building type (36) by census tract in the study region. Results are presented for each design level and construction quality bias. Damage state probabilities are determined for i) structural elements, ii) non-structural drift-sensitive elements, and iii) non-structural acceleration-sensitive elements.	a) Structural Damage State Probabilities b) Non-structural Damage State Probabilities c) Structural Damage State Building Counts
General Building Type	**HAZUS** determines the damage state probability for each general building type (7) by census tract in the study region. Results are presented for each design level and construction quality bias. Damage state probabilities are determined for i) structural elements, ii) non-structural drift-sensitive elements, and iii) non-structural acceleration-sensitive elements.	a) Structural Damage State Probabilities b) Non-structural Damage State Probabilities c) Structural Damage State Building Counts
Specific Occupancy Class	**HAZUS** determines the damage state probability for each specific occupancy (28) by census tract in the study region. Results are presented for each construction quality bias. Damage state probabilities are determined for i) structural elements, ii) non-structural drift-sensitive elements, and iii) non-structural acceleration-sensitive elements.	a) Structural Damage State Probabilities b) Non-structural Damage State Probabilities c) Structural Damage State Occupancy Counts
General Occupancy Class	**HAZUS** determines the damage state probability for each general occupancy (6) by census tract in the study region. Damage state probabilities are determined for I) structural elements, ii) non-structural drift-sensitive elements, and iii) non-structural acceleration-sensitive elements.	a) Structural Damage State Probabilities b) Non-structural Damage State Probabilities c) Structural Damage State Occupancy Counts

The **Results|General Building Stock** menu option is used to assess the output of the damage module. Results are provided in a tabular format (see Figures 10.7 and 10.8) or in a map form (Figures 10.9 through 10.11). In both cases the following information can be displayed:

- Probability of none, slight, moderate, extensive or complete structural damage, acceleration sensitive non- structural damage or drift sensitive non- structural damage.
- Probability of at least slight, at least moderate, at least extensive for structural or either type of non-structural damage.

To thematically map a given value, select its column by clicking on the header, and then clicking **Map**. Click on **Return|Return to Table** to go back to the dialog that displays tabular results.

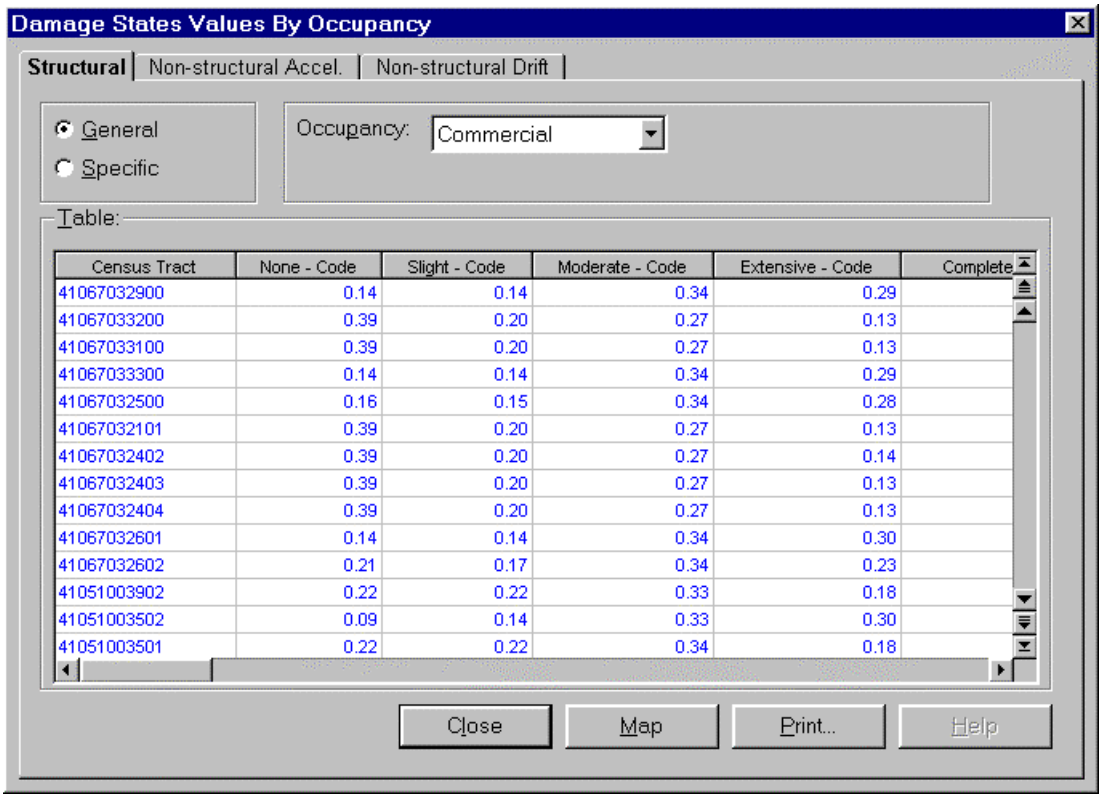


Figure 10.7 Damage state probabilities by general occupancy.

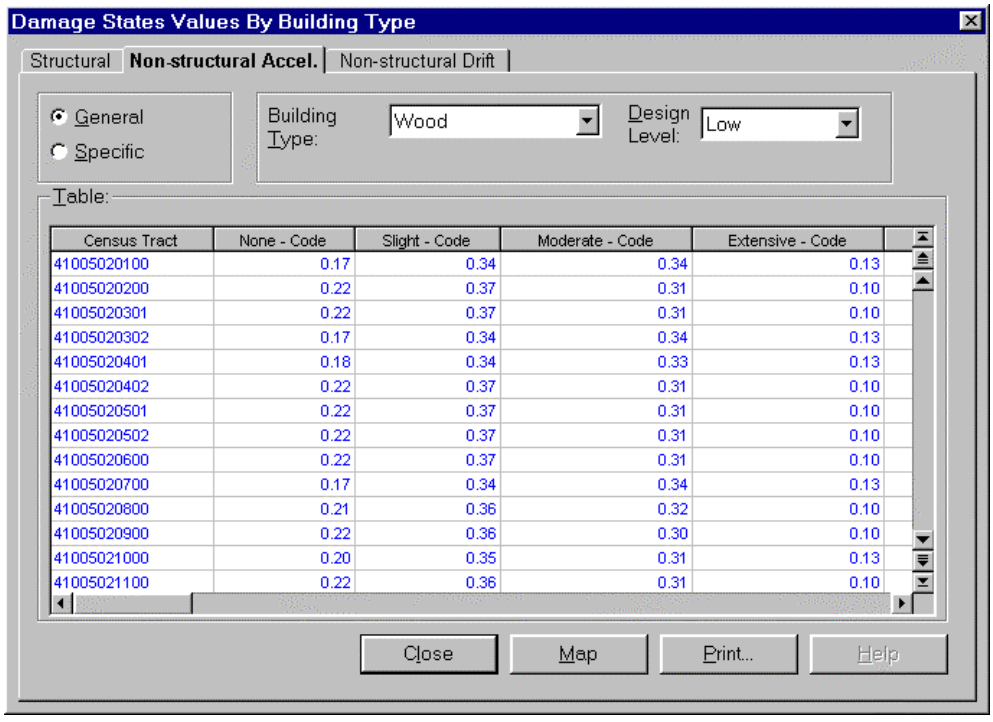


Figure 10.8 Damage state probabilities by general building type.

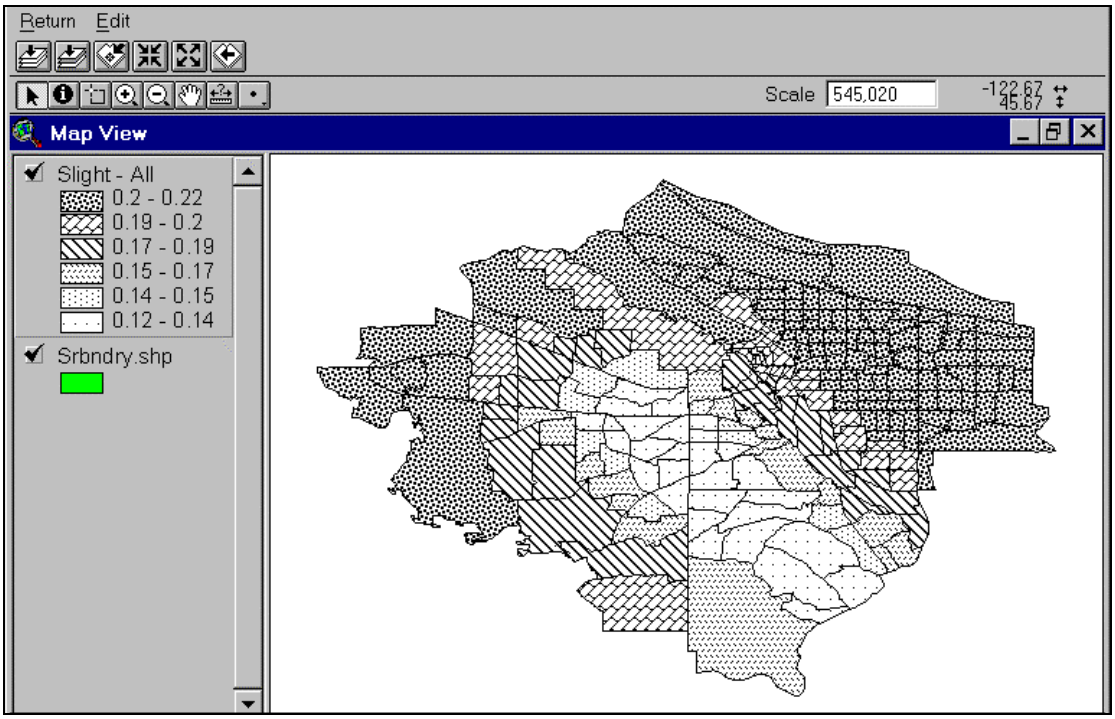


Figure 10.9 Map of probability of slight structural damage for commercial occupancy.

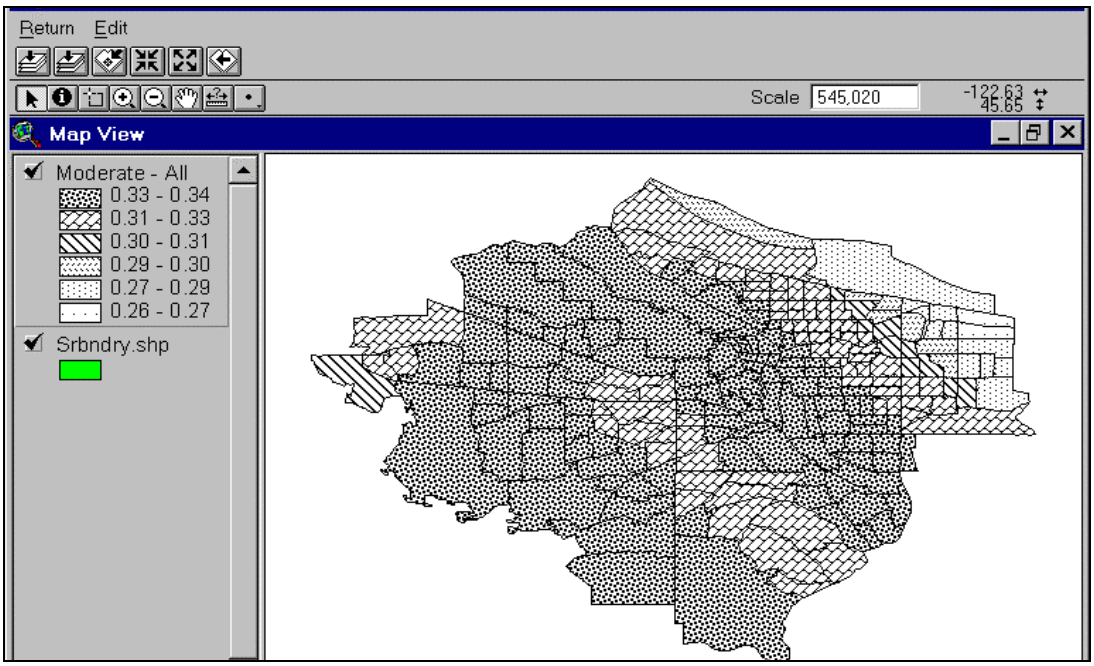


Figure 10.10 Map of moderate structural damage for retail trade (COM 1).

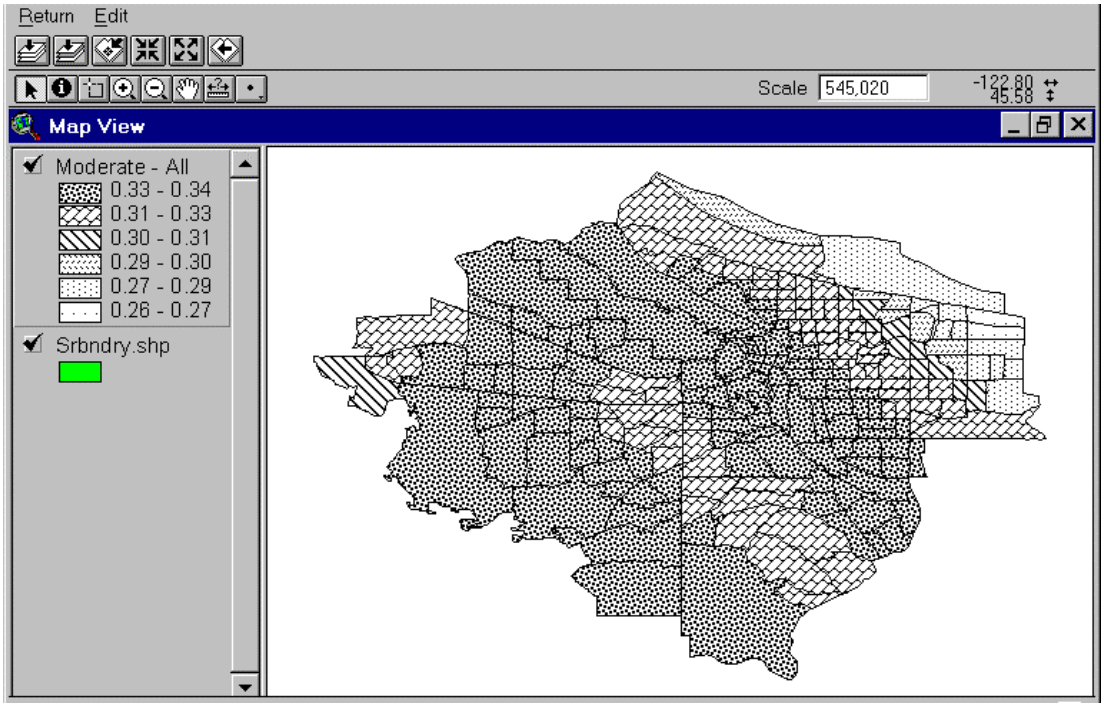


Figure 10.11 Map of moderate non-structural drift sensitive damage for retail trade (COM 1).

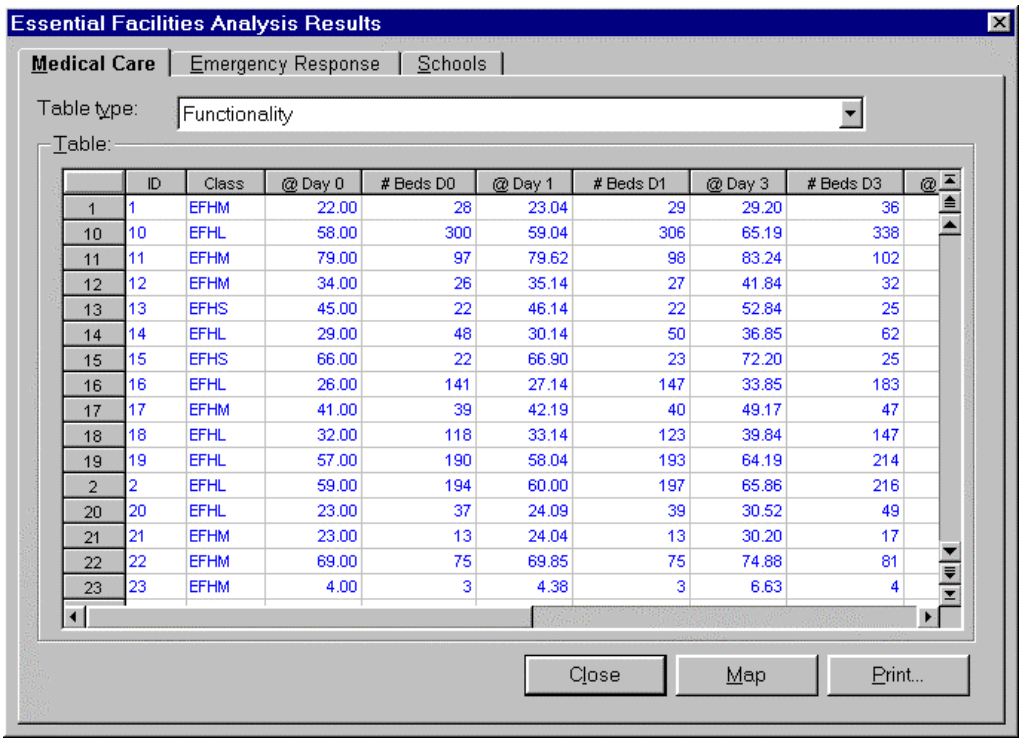
10.5 Direct Physical Damage - Essential Facilities

HAZUS provides information about the damage state probability of the study region's essential facilities. In contrast to the general building stock, where damage probabilities are calculated for groups of buildings, for essential facilities the damage probabilities are estimated for each individual facility. As with the general building stock, the damage states are none, slight, moderate, extensive and complete. Both structural and non-structural damage is considered. As can be seen in Table 10.4, damage state probabilities are estimated for health care facilities, police and fire stations, emergency operation centers and schools. In addition, loss of beds and facility functionality is computed as a function of time for health care facilities.

Output of the essential facilities damage module can be obtained by using the **Results|Essential Facilities** menu. As with the general building stock, results are provided in a tabular format or in a map form. An example of the functionality of health care facilities is found in Figure 10.12. To thematically map a given value, select its column by clicking on the header, and then clicking **Map**. Click on **Return|Return to Table** to go back to the dialog that displays tabular results.

Table 10.4 Direct Physical Damage Module Outputs - Essential Facilities

Facility Type	Description of Output	Measure
Health Care Facilities	**HAZUS** determines the damage state probabilities for each health care facility in the study region. Damage state probabilities are determined for i) structural elements, ii) non-structural drift-sensitive elements, and iii) non-structural acceleration-sensitive elements. The expected reduction in available beds for each facility is also determined.	a) Structural Damage State Probabilities b) Non-structural Damage State Probabilities c) Loss of Beds and Facility Functionality
Police/Fire Stations Emergency Operations Centers Schools	**HAZUS** determines the damage state probabilities for each facility in the study region. Damage state probabilities are determined for i) structural elements, ii) non-structural drift-sensitive elements, and iii) non-structural acceleration-sensitive elements.	a) Structural Damage State Probabilities b) Non-structural Damage State Probabilities c) Functionality @ Day 1



	ID	Class	@ Day 0	# Beds D0	@ Day 1	# Beds D1	@ Day 3	# Beds D3	@
1	1	EFHM	22.00	28	23.04	29	29.20	36	
10	10	EFHL	58.00	300	59.04	306	65.19	338	
11	11	EFHM	79.00	97	79.62	98	83.24	102	
12	12	EFHM	34.00	26	35.14	27	41.84	32	
13	13	EFHS	45.00	22	46.14	22	52.84	25	
14	14	EFHL	29.00	48	30.14	50	36.85	62	
15	15	EFHS	66.00	22	66.90	23	72.20	25	
16	16	EFHL	26.00	141	27.14	147	33.85	183	
17	17	EFHM	41.00	39	42.19	40	49.17	47	
18	18	EFHL	32.00	118	33.14	123	39.84	147	
19	19	EFHL	57.00	190	58.04	193	64.19	214	
2	2	EFHL	59.00	194	60.00	197	65.86	216	
20	20	EFHL	23.00	37	24.09	39	30.52	49	
21	21	EFHM	23.00	13	24.04	13	30.20	17	
22	22	EFHM	69.00	75	69.85	75	74.88	81	
23	23	EFHM	4.00	3	4.38	3	6.63	4	

Figure 10.12 Functionality of health care facilities.

10.6 High Potential Loss Facilities

High potential loss facilities tend to be unique and complex facilities that would require in-depth evaluation by structural and geotechnical engineers to assess their vulnerability to earthquakes. These types of facilities are often designed to codes and standards that exceed those for general building stock. Thus, the vulnerability curves that are used for general building stock may be inappropriate for high potential loss facilities. It is likely

that the user/engineer will need to define vulnerability curves that are specific to these facilities. Furthermore, often the owners of these facilities have already performed in-depth, site-specific seismic hazard analyses. For these reasons, **HAZUS** is limited to providing information concerning the location of the study region's high potential loss facilities (see Table 10.5). This can serve as a first step in developing mitigation and preparedness efforts. You may opt to perform a vulnerability analysis of a specific facility, and include the results of the special study with the results of the methodology. Locations of and details about high potential loss facilities are found in the **Inventory|High Potential Loss Facilities|Inventory Data** menu. Results for military facilities are obtained through the **Results|Military Installations** menu.

Table 10.5 Direct physical damage module outputs - high potential loss facilities

Component	Description of Output	Measure
Dams	**HAZUS** provides the locations of dams in the study region.	List of and locations of dams
Nuclear Facilities	**HAZUS** provides the locations of nuclear power facilities in the study region.	List of and locations of nuclear power facilities
Military facilities	**HAZUS** determines the damage state probabilities for each facility in the study region. Damage state probabilities are determined for i) structural elements, ii) non-structural drift-sensitive elements, and iii) non-structural acceleration-sensitive elements.	a) Structural Damage State Probabilities b) Non-structural Damage State Probabilities

10.7 Direct Physical Damage - Lifelines

Lifeline systems are vital to the functionality of a community. Damage to these systems after an earthquake can be devastating in terms of the health and safety of the citizens. After the Great Hanshin earthquake in 1995, the water supply system was so severely damaged that people had to rely on trucked-in water. Damage to railway and road systems prevented emergency response personnel from bringing food, water and other supplies into the region. Over 900,000 households were without electricity and 800,000 households without gas in the middle of winter. Damage to roads and blockages of roads due to collapsed buildings prevented police, fire fighters and rescuers from fighting fires and attending to the trapped and injured.

Losses to the community that result from damage to lifelines can be much greater than the costs of repairing the systems. For example, damage to the Kobe harbor, one of the busiest in Japan, stopped the import and export of materials that were essential to the operation of many manufacturing plants in Japan. Factories were forced to close down for lack of materials. Recovery of the region will depend to a great degree on how quickly lifelines can be restored to full functionality. Therefore, assessment of the vulnerability of lifeline systems is a very important part of developing regional emergency preparedness and response plans.

In **HAZUS**, damage to lifeline systems is described in terms of damage to components. Detailed systems analyses are not performed, although simplified system analyses are performed for water systems and electric power. Damage is reported in terms of the

probability of reaching or exceeding a specified level of damage when subjected to a given level of ground motion or permanent ground deformation. Associated with each damage state is a restoration curve that is used to evaluate the time required to bring the system back to full functionality.

A probability of functionality is defined as the probability, given an initial level of damage after the earthquake, of the component operating at a certain capacity after a specified period of time. For example, a highway bridge might be found to have the following probabilities of damage, based upon experiencing 0.6g peak ground acceleration and 12 inches of permanent ground deformation.

- No damage 3% chance
- Slight damage 9% chance
- Moderate damage 20% chance
- Extensive damage 44% chance
- Complete damage 24% chance

Based upon this estimate of damage, the expected functionality of the bridge would be

- 14% functional after one day,
- 26% functional after 3-days,
- 34% functional after 7 days,
- 39% functional after 30 days, and
- 60% functional after a 3-month restoration period.

Another interpretation of these results is that after one day, 14% of the bridges of this type would be functional and after 3 months, 60% of these bridges would be functional. Interdependency of the components on overall transportation system functionality is not addressed by the methodology. Lifelines are divided into transportation systems and utility systems. Table 10.6 summarizes the outputs for each of the seven transportation lifeline systems.

Table 10.6 Direct Physical Damage Module Outputs - Transportation Systems

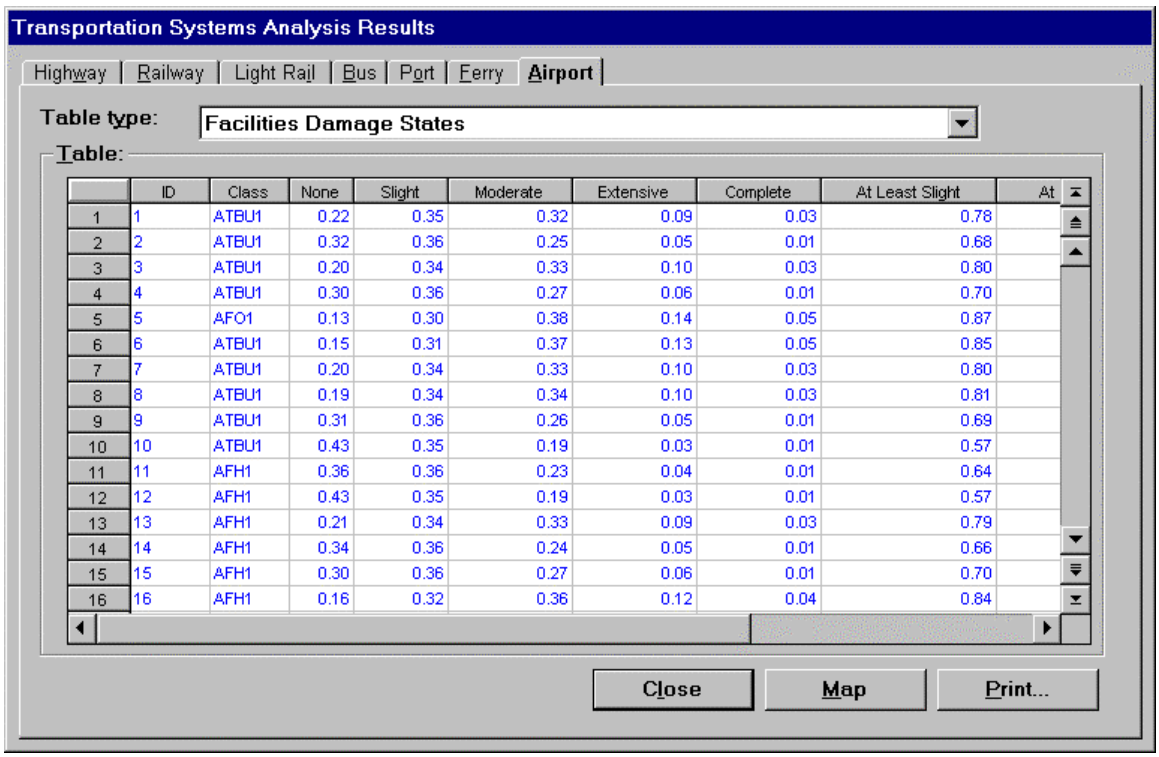
System	Description of Output	Measure
Highway System Railway System Light Rail Bus Ferry Port Airport	a) **HAZUS** determines the damage state probability for each transportation system component in the study region.	a) Component Damage State Probabilities
	b) **HAZUS** determines the probability of functionality for each transportation system component at discrete time intervals.	b) Component Probability of Functionality

Table 10.7 summarizes the outputs of **HAZUS** for the study region's utility system components. A simplified system analysis is performed for potable water systems and electric power systems. These analyses make simplified assumptions about the serviceability of the systems based on the number of pipe leaks and breaks or the functionality of medium voltage substations.

Table 10.7 Direct Physical Damage Module Outputs - Utility Systems

System	Description of Output	Measure
Potable Water	a) **HAZUS** determines the damage state probabilities for each potable water component in the study region. b) **HAZUS** determines the probability of functionality for each potable water component at discrete time intervals. c) **HAZUS** supports simplified potable water system analysis for the study region.	a) Component Damage State Probabilities b) Component Probability of Functionality c) # of Households without water
Waste Water Natural Gas Crude and Refined Oil Pipeline Communication	a) **HAZUS** determines the damage state probabilities for each system component in the study region. b) **HAZUS** determines the probability of functionality for each system component at discrete time intervals.	a) Component Damage State Probabilities b) Component Probability of Functionality
Electric Power	a) **HAZUS** determines the damage state probabilities for each electric power component in the study region. b) **HAZUS** determines the probability of functionality for each electric power component at discrete time intervals. c) **HAZUS** supports simplified system analysis for the study region.	a) Component Damage State Probabilities b) Component Probability of Functionality c) # of Households without power

Output of the lifeline module can be viewed in terms of damage states or in terms of functionality and can be displayed in a tabular or map format. Figure 10.13 shows a table of the damage to airport facilities for the study region. For each of the airports in the study region (identified by ID number), the probability of being in one of the five damage states is tabulated. For airport facility number 1, the probability of no damage is 0.22, slight damage is 0.35 and moderate damage is 0.32. This information can be mapped, as shown in Figure 10.14, by clicking on the **Map** button. Each airport facility is identified by a symbol. The shape (or color) of the symbol is associated with a range of probabilities. For example, if the symbol is square, the probability of slight damage is between 0.34 and 0.35. Users familiar with ArcView, have the option of zooming in on any area and viewing that area more closely as shown in Figure 10.15.



	ID	Class	None	Slight	Moderate	Extensive	Complete	At Least Slight	At
1	1	ATBU1	0.22	0.35	0.32	0.09	0.03	0.78	
2	2	ATBU1	0.32	0.36	0.25	0.05	0.01	0.68	
3	3	ATBU1	0.20	0.34	0.33	0.10	0.03	0.80	
4	4	ATBU1	0.30	0.36	0.27	0.06	0.01	0.70	
5	5	AFO1	0.13	0.30	0.38	0.14	0.05	0.87	
6	6	ATBU1	0.15	0.31	0.37	0.13	0.05	0.85	
7	7	ATBU1	0.20	0.34	0.33	0.10	0.03	0.80	
8	8	ATBU1	0.19	0.34	0.34	0.10	0.03	0.81	
9	9	ATBU1	0.31	0.36	0.26	0.05	0.01	0.69	
10	10	ATBU1	0.43	0.35	0.19	0.03	0.01	0.57	
11	11	AFH1	0.36	0.36	0.23	0.04	0.01	0.64	
12	12	AFH1	0.43	0.35	0.19	0.03	0.01	0.57	
13	13	AFH1	0.21	0.34	0.33	0.09	0.03	0.79	
14	14	AFH1	0.34	0.36	0.24	0.05	0.01	0.66	
15	15	AFH1	0.30	0.36	0.27	0.06	0.01	0.70	
16	16	AFH1	0.16	0.32	0.36	0.12	0.04	0.84	

Figure 10.13 Output of the lifeline module: damage to airport facilities.

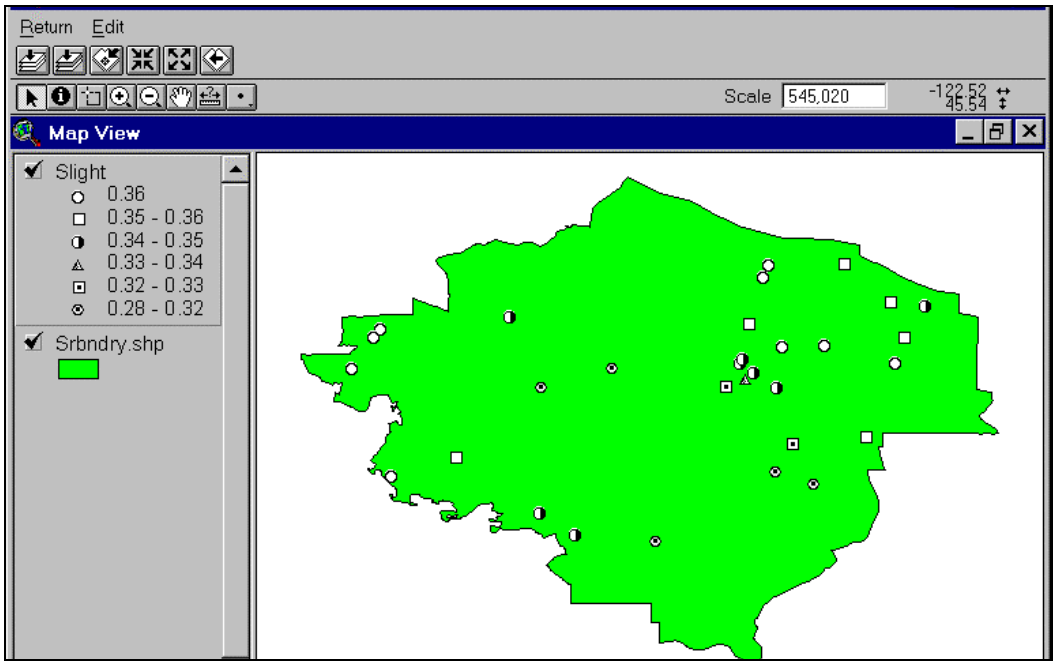


Figure 10.14 Output of the lifeline module: map of probability of slight damage to airport facilities for entire study region.

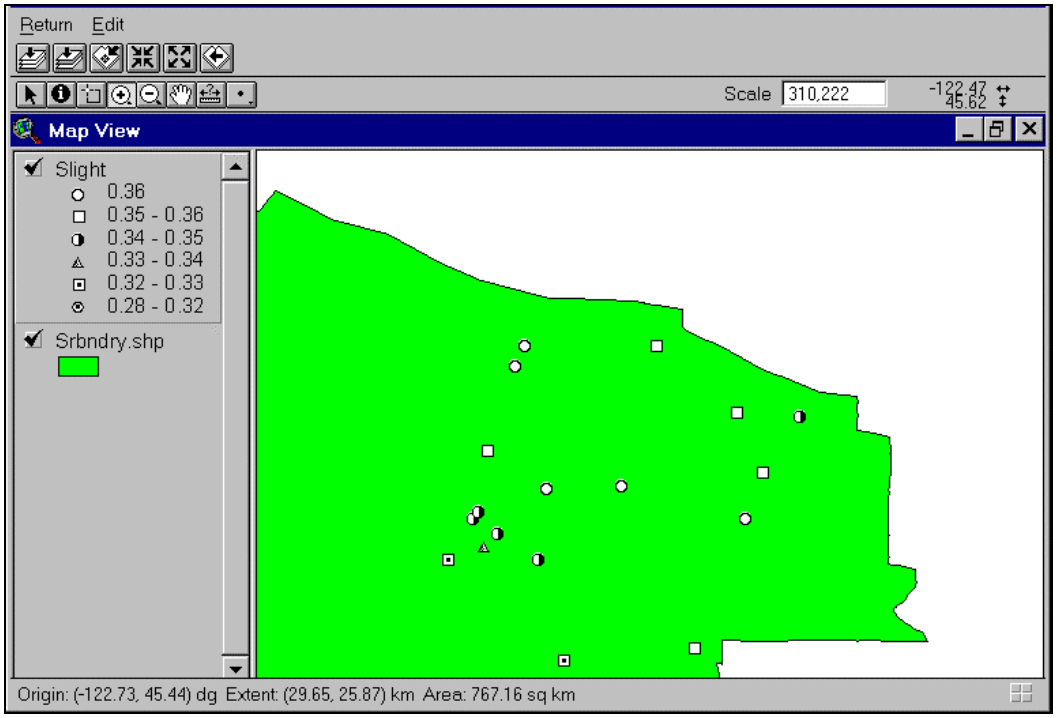
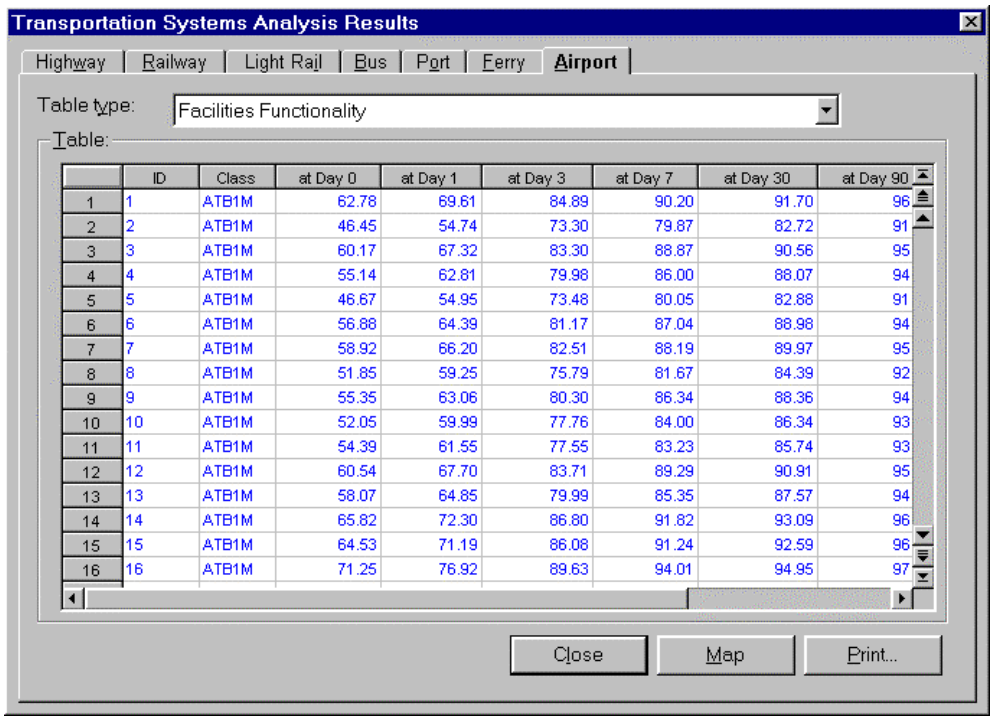


Figure 10.15 Map of probability of slight damage to airport facilities for a portion of the study region.

Figure 10.16 shows a table of the functionality of airport facilities at specified periods after the occurrence of the scenario earthquake. According to this table, facility number 1 would be functional with a 63% probability immediately after the earthquake, and functional with a 96% probability after 90 days. Functionality can be mapped, as shown

in Figure 10.17, by clicking on the **Map** button. Facilities are mapped as "operational" or "non-operational". The user must specify a "confidence level" above which the facility is considered operational. In Figure 10.18 the "confidence level" is chosen to be 75%, indicating that if the probability of functionality is greater than 75%, the facility will be considered operational. Based on this definition of operational, many of the airport terminals near the epicenter will be non-operational the day after the earthquake.



	ID	Class	at Day 0	at Day 1	at Day 3	at Day 7	at Day 30	at Day 90
1	1	ATB1M	62.78	69.61	84.89	90.20	91.70	96
2	2	ATB1M	46.45	54.74	73.30	79.87	82.72	91
3	3	ATB1M	60.17	67.32	83.30	88.87	90.56	95
4	4	ATB1M	55.14	62.81	79.98	86.00	88.07	94
5	5	ATB1M	46.67	54.95	73.48	80.05	82.88	91
6	6	ATB1M	56.88	64.39	81.17	87.04	88.98	94
7	7	ATB1M	58.92	66.20	82.51	88.19	89.97	95
8	8	ATB1M	51.85	59.25	75.79	81.67	84.39	92
9	9	ATB1M	55.35	63.06	80.30	86.34	88.36	94
10	10	ATB1M	52.05	59.99	77.76	84.00	86.34	93
11	11	ATB1M	54.39	61.55	77.55	83.23	85.74	93
12	12	ATB1M	60.54	67.70	83.71	89.29	90.91	95
13	13	ATB1M	58.07	64.85	79.99	85.35	87.57	94
14	14	ATB1M	65.82	72.30	86.80	91.82	93.09	96
15	15	ATB1M	64.53	71.19	86.08	91.24	92.59	96
16	16	ATB1M	71.25	76.92	89.63	94.01	94.95	97

Figure 10.16 Output of the lifeline module: functionality of airport facilities reported by number of days since the occurrence of the earthquake.

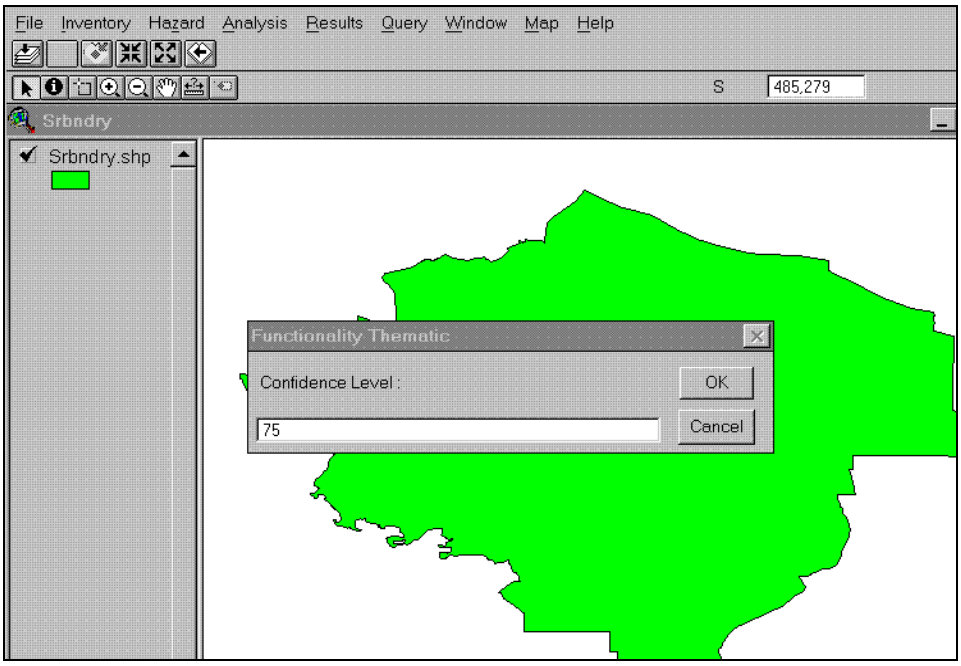


Figure 10.17 Selection of confidence level.

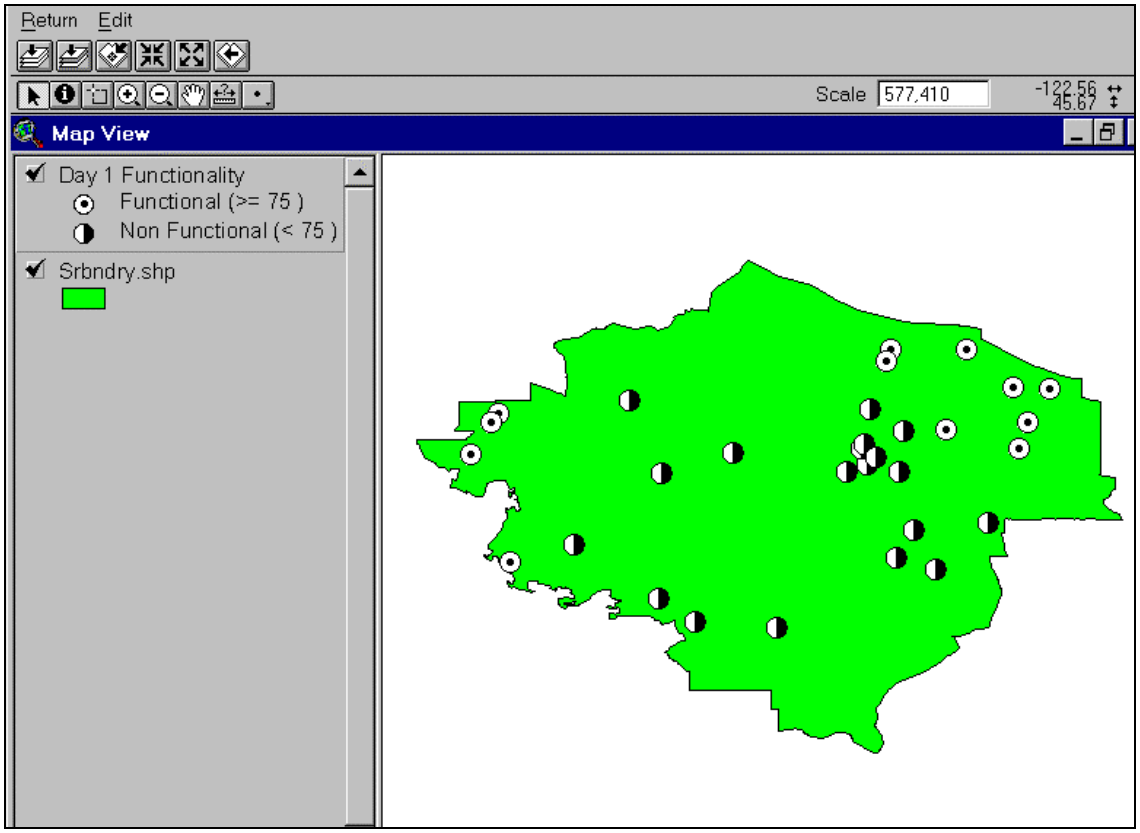


Figure 10.18 Output of the lifeline module: map functionality of airport terminal buildings.

10.8 Induced Physical Damage

HAZUS includes information about earthquake-related flooding to enable users to design programs to reduce the likelihood of dam or levee failure and to prepare to cope with those floods that may occur. Development of inundation maps requires an understanding of the downstream topography and the involvement of an experienced hydrologist. In the case of tsunamis, inundation models are complex and are in many cases still in the development stage; therefore, **HAZUS** does not produce inundation maps. Instead, as a first step in assessing the risk to a study region, all dams and levees are identified. The existing national inventory of dams that is provided with the software includes a hazard classification (low, significant, high) based on the downstream urban development and potential economic loss. The potential for tsunamis and seiches are assessed (by the user outside **HAZUS**) without any estimate of size or consequence. Table 10.8 summarizes the outputs that are available from **HAZUS**.

Table 10.8 Induced Physical Damage Module Outputs - Inundation

Component	Description of Output	Measure
Tsunami	a) The methodology provides rules to determine if tsunamis are a threat to the study region. b) The user can import existing tsunami inundation maps and overlay with population and economic value maps.	a) Qualify Potential Threat b) Exposed Population Exposed Value ($)
Seiche	a) The methodology provides rules to determine if seiches are a threat on any body of water in the study region. b) The user can import existing seiche inundation maps and overlay with population and economic value maps.	a) Qualify Potential Threat b) Exposed Population Exposed Value ($)
Dam Failure	a) **HAZUS** displays the location of all dams in the study region and (for the default database) ranks the potential impact of the dam failure. b) The user can import existing dam failure inundation maps and overlay with population and economic value maps.	a) List of and Locations of Dams and Quantification of Potential Hazard b) Exposed Population Exposed Value ($)
Levee Failure	a) **HAZUS** displays the location of the levees in the study region. b) The user can import existing levee failure inundation maps and overlay with population and economic value maps.	a) List of and Locations of Levees b) Exposed Population Exposed Value ($)

For all four inundation types, **HAZUS** has the ability to import existing inundation maps. These can then be overlaid with population density maps or maps of inventory to estimate exposed population and exposed inventory. The output of the inundation module is a display of the inundation maps that were specified in the data window shown in Figure 9.32. An example is shown in Figure 10.19. To access this map, use the **Map|Inundation Maps|Dams** menu. This map can be overlaid with population data to obtain an understanding of the exposed population, as shown in Figure 10.20. Alternatively, you can view a table of population, value and area exposure by census tract using the **Results|Inundation** menu (see Figure 10.21). This output is only available if

an inundation map has been specified. Highlighting the appropriate column and clicking on the Map button can map any one of the outputs in Figure 10.21.

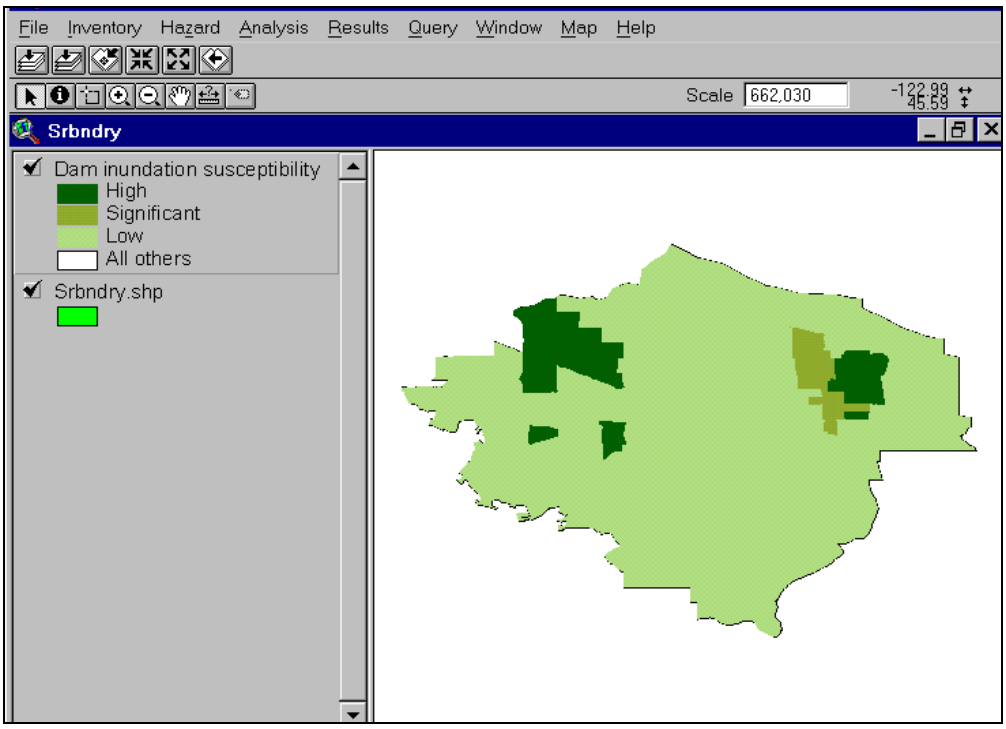


Figure 10.19 Display of inundation potential map.

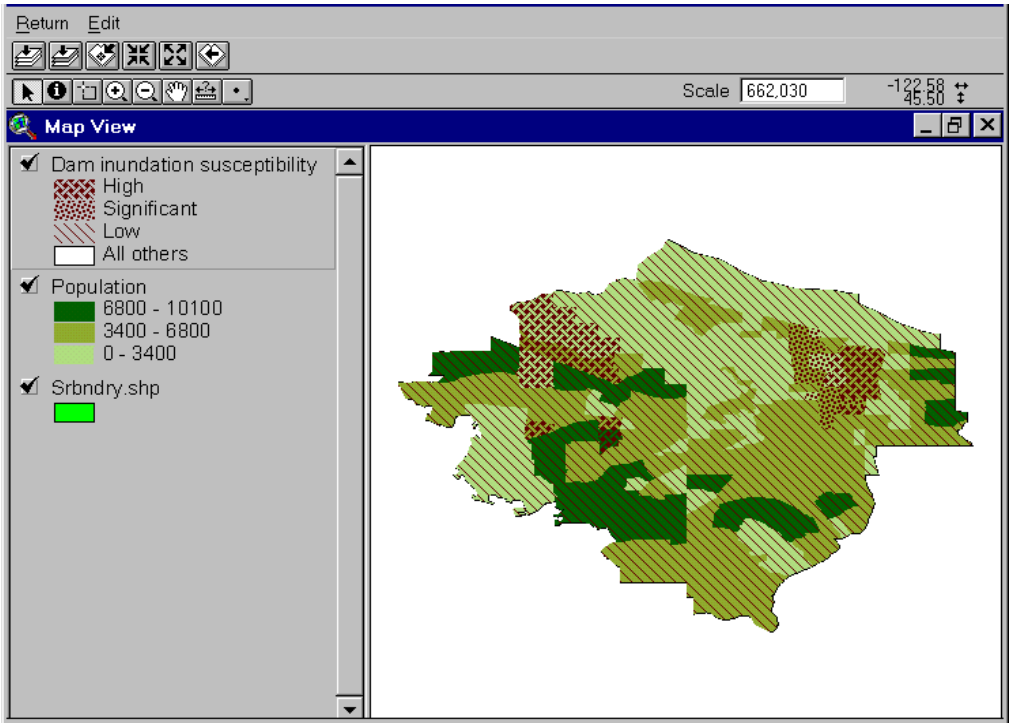


Figure 10.20 Population data overlaid with the inundation potential map.

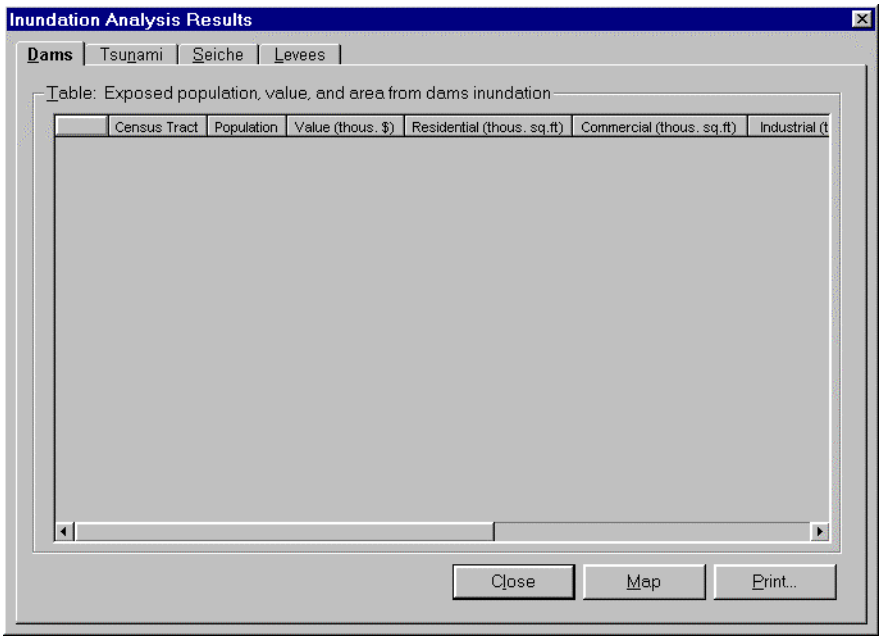


Figure 10.21 Tabulation of exposed population, value and area resulting from inundation map.

Assessment of the consequences of a hazardous materials release requires an understanding of the amounts and types of materials that are released as well as, in some cases, a model of a gaseous plume. A single facility may house many toxic and hazardous materials. Without visiting a facility, assessing the vulnerability of the structure and auditing how materials are stored, it is impossible to give a meaningful estimate of risk. Therefore **HAZUS** does not perform any analysis on hazardous. Locations of hazardous materials facilities can be mapped and overlaid with ground motion, population and inventory maps. This can provide a preliminary assessment of consequences, which can then be followed up with detailed site-specific studies. In addition, the hazardous facility database can be sorted in a variety of ways allowing the user to view only certain types of materials, facilities with large amounts, highly vulnerable facilities, etc. Table 10.9 summarizes the information available from the hazardous materials module.

Table 10.9 Induced Physical Damage Module - Hazardous Material Release

Component	Description	Measure
Hazardous Materials Facilities	a) **HAZUS** provides the location of the hazardous material facilities located in the study region. b) **HAZUS** provides the types and amounts of hazardous materials stored at each location and the health hazard associated with each chemical. c) The user can overlay a map of hazardous material facilities with ground shaking, population, and economic value maps to interrogate the consequences of release at a particular site.	a) List of and Locations of Facilities Containing Hazardous Materials b) Type/Amount of Material Stored at Each Facility

There us no output for the hazardous materials module. The inventory information can be accessed using **Inventory|Hazardous Materials.** Form Hazardous Material database you can get a listing of the materials and plots of locations of sites as shown in Figures 10.22 and 10.23. Clicking the Map button at the bottom of Figure 10.22 generated the output shown in Figure 10.23. The information in the small box at the left-hand side of Figure 10.23 was retrieved using the information tool (**i**) in the ArcView Main menu. By using the information tool and clicking on any one of the sites, you can access all of the stored data for that site.

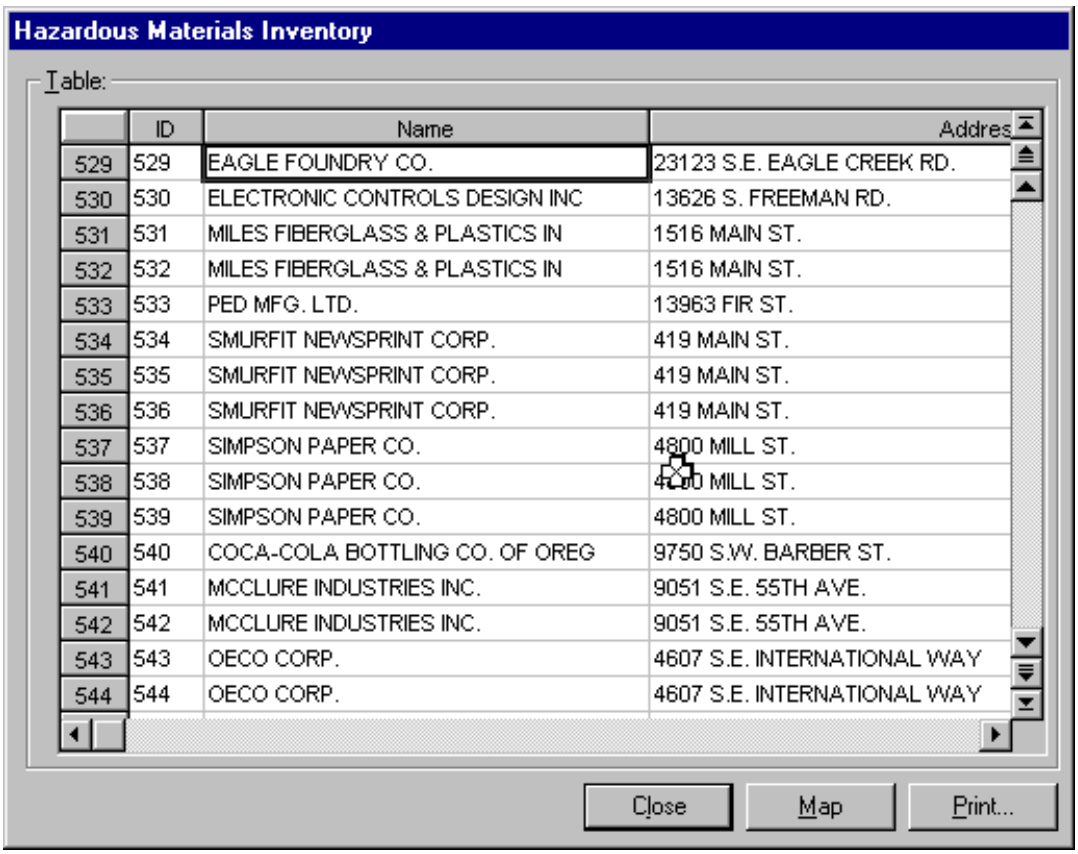


Figure 10.22 Default hazardous material database.

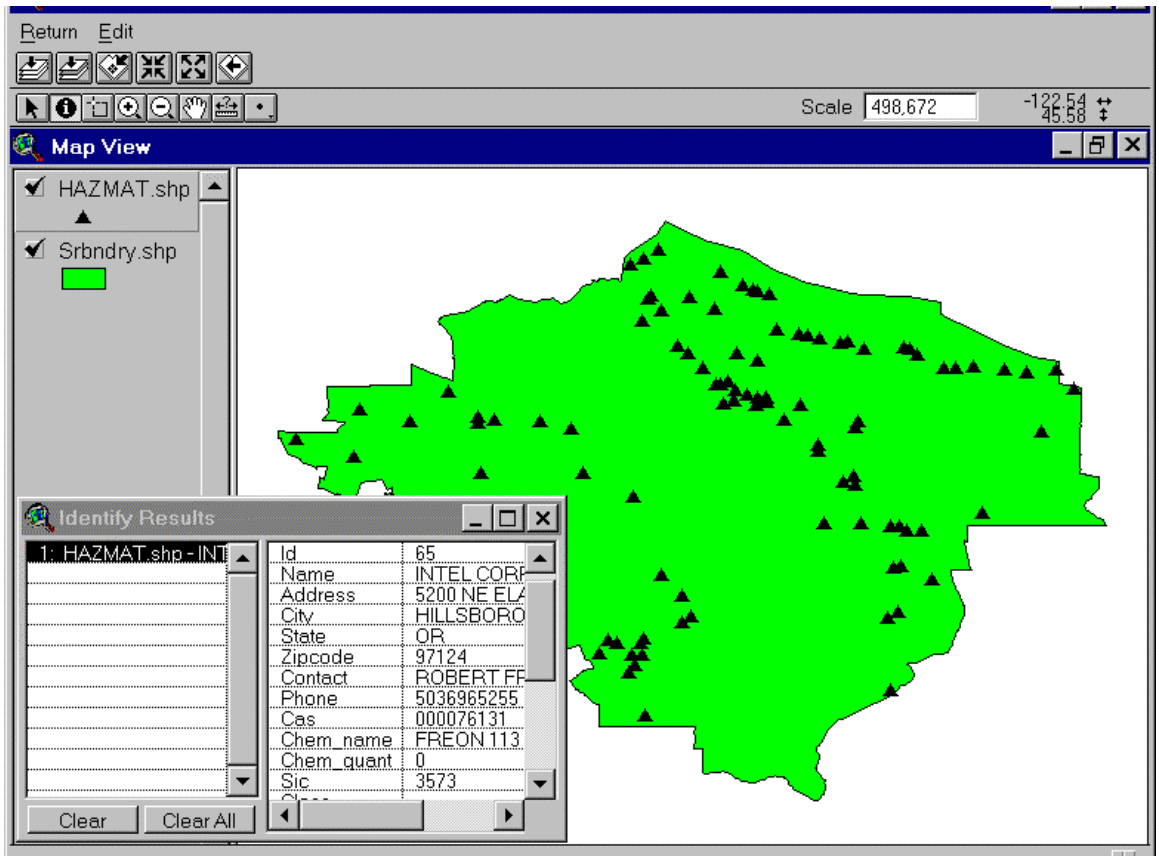


Figure 10.23 Map of default hazardous materials database

Another feature of **HAZUS** is that you can query the database and plot specific types of data. In Figure 10.27, all of the sites at which ammonia or chlorine are stored have been identified and are plotted as large triangles. This was done using the **Query** menu.

To create such a map, follow these steps. Plot the hazardous materials database for your region using the **Map** button at the bottom of the window shown in Figure 10.22. Then click on the **Return** menu at the upper left-hand corner of the map. Click on **Return to Table**. Close the table using the **Close** button at the bottom of the window (see Figure 10.22). Click on the **Query|Query** menu and the dialog box shown in Figure 10.24 will appear. By double clicking on different selection parameters and using various pull down menus, you can create a query from the table called HAZMAT.

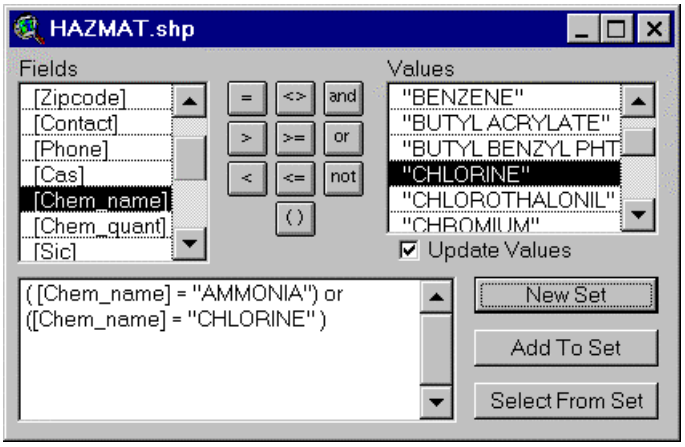


Figure 10.24 Developing a query to identify sites that store ammonia or chlorine.

The facilities that satisfy the selection criteria will appear highlighted on the inventory map as shown in Figure 10.25.

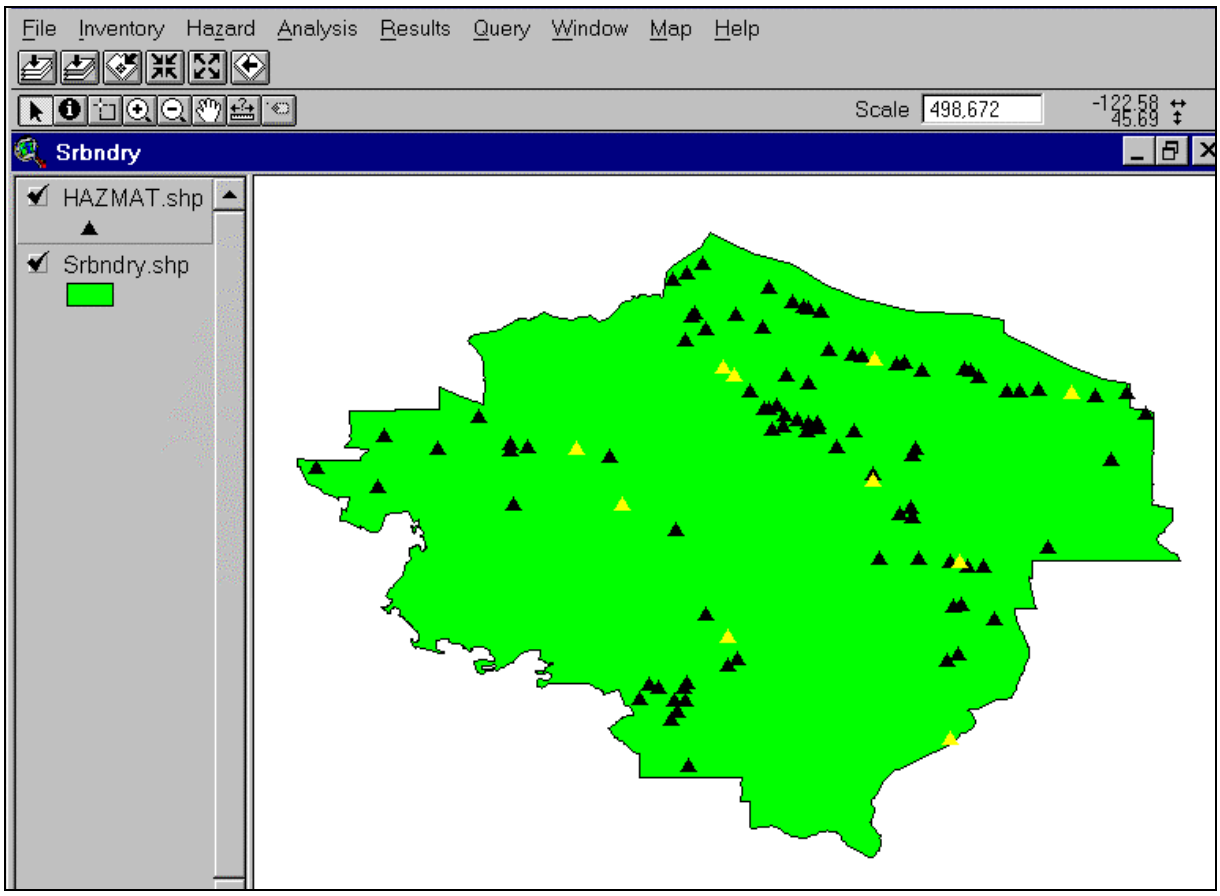


Figure 10.25 The result of the query

A complete Fire Following Earthquake Model requires extensive input including the types and density of fuel, the number of fire fighting apparatus, the functionality of the water system, the occurrence of hazardous materials releases, wind conditions, and

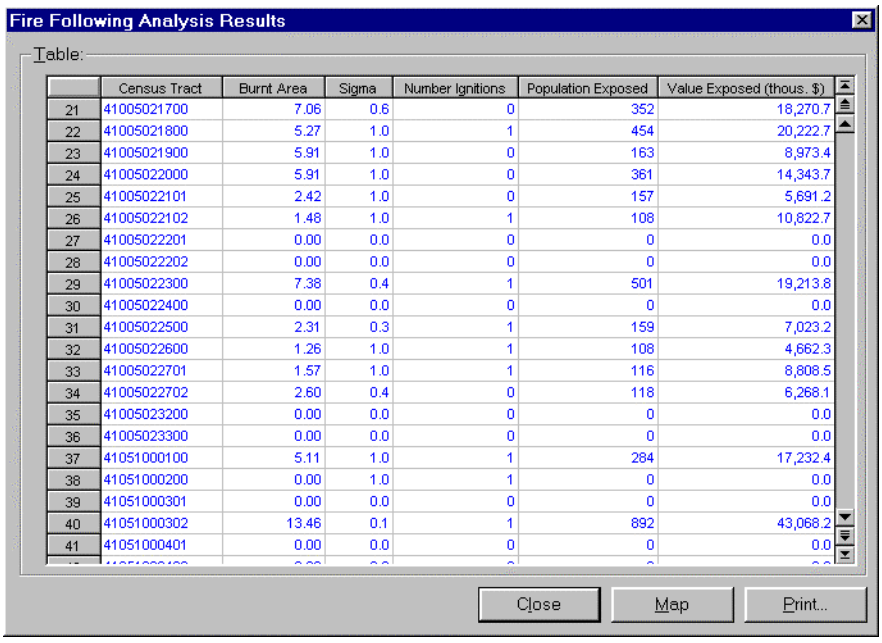
others. To simplify the input, **HAZUS** limits the analysis to an estimate of the number of ignitions, an estimate of the size of the potential burned area, and estimates of exposed population and exposed inventory.

Table 10.10 Induced Physical Damage Module Outputs - Fire Following Earthquake

Component	Description of Output	Measure
Ignition	a) **HAZUS** determines the expected number of fire ignitions by census tract for the study region.	a) Number of ignitions
Burned Area	a) **HAZUS** determines the expected burned area by census tract for the study region. b) Expected burned area is combined with population and economic value to estimate exposed population and inventory.	a) Percentage of Burned Area b) Exposed Population Exposed Value ($)

The outputs from Fire Following Earthquake Model are presented in **HAZUS** in a table as shown in Figure 10.26. For each census tract in the study region, the following values are displayed:

- Best estimates of the percent of the census tract that has been burned
- Standard deviation of the estimate of percent of burned area
- Number of ignitions in the census tract
- The population in the census tract that is exposed to fire (% burned area X total population in census tract)
- The value of inventory (in dollars) in the census tract fire exposed to fire (% burned area X total building value in census tract)



	Census Tract	Burnt Area	Sigma	Number Ignitions	Population Exposed	Value Exposed (thous. $)
21	41005021700	7.06	0.6	0	352	18,270.7
22	41005021800	5.27	1.0	1	454	20,222.7
23	41005021900	5.91	1.0	0	163	8,973.4
24	41005022000	5.91	1.0	0	361	14,343.7
25	41005022101	2.42	1.0	0	157	5,691.2
26	41005022102	1.48	1.0	1	108	10,822.7
27	41005022201	0.00	0.0	0	0	0.0
28	41005022202	0.00	0.0	0	0	0.0
29	41005022300	7.38	0.4	1	501	19,213.8
30	41005022400	0.00	0.0	0	0	0.0
31	41005022500	2.31	0.3	1	159	7,023.2
32	41005022600	1.26	1.0	1	108	4,662.3
33	41005022701	1.57	1.0	1	116	8,808.5
34	41005022702	2.60	0.4	0	118	6,268.1
35	41005023200	0.00	0.0	0	0	0.0
36	41005023300	0.00	0.0	0	0	0.0
37	41051000100	5.11	1.0	1	284	17,232.4
38	41051000200	0.00	1.0	1	0	0.0
39	41051000301	0.00	0.0	0	0	0.0
40	41051000302	13.46	0.1	1	892	43,068.2
41	41051000401	0.00	0.0	0	0	0.0

Figure 10.26 Output of fire following earthquake module.

Highlighting the column and then clicking on the Map button will map any of the columns in Figure 10.26. The "Burnt Area (%)" column has been mapped in Figure 10.27. A summary report of the output of the Fire Following Earthquake Model can also be printed to the screen or to a printer.

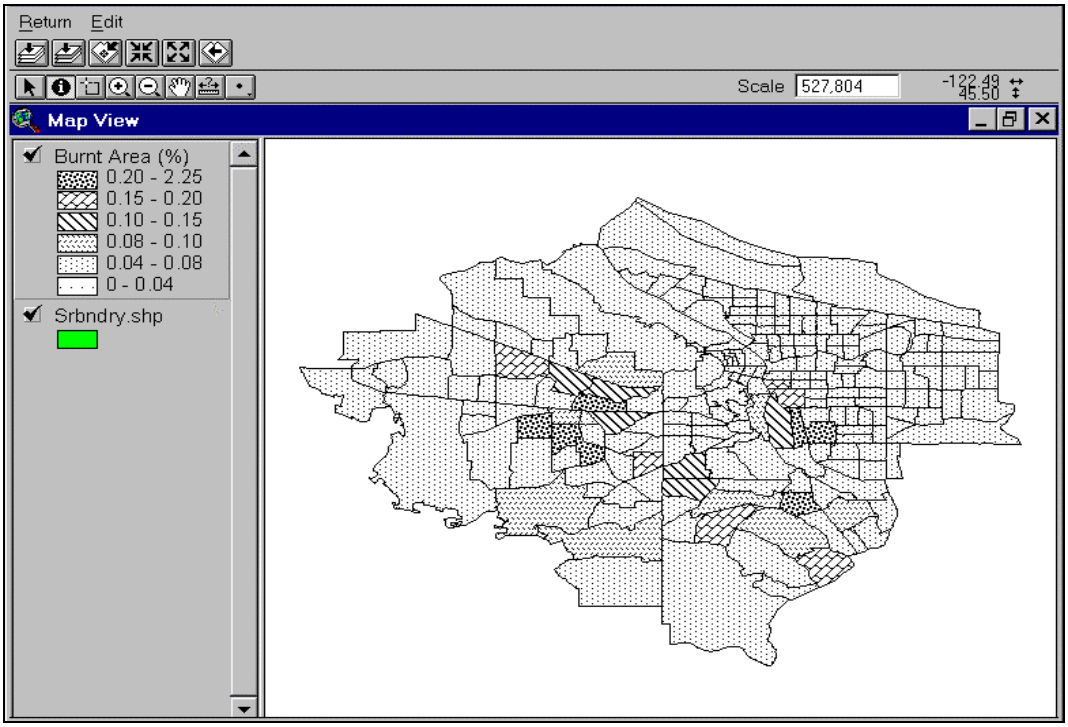


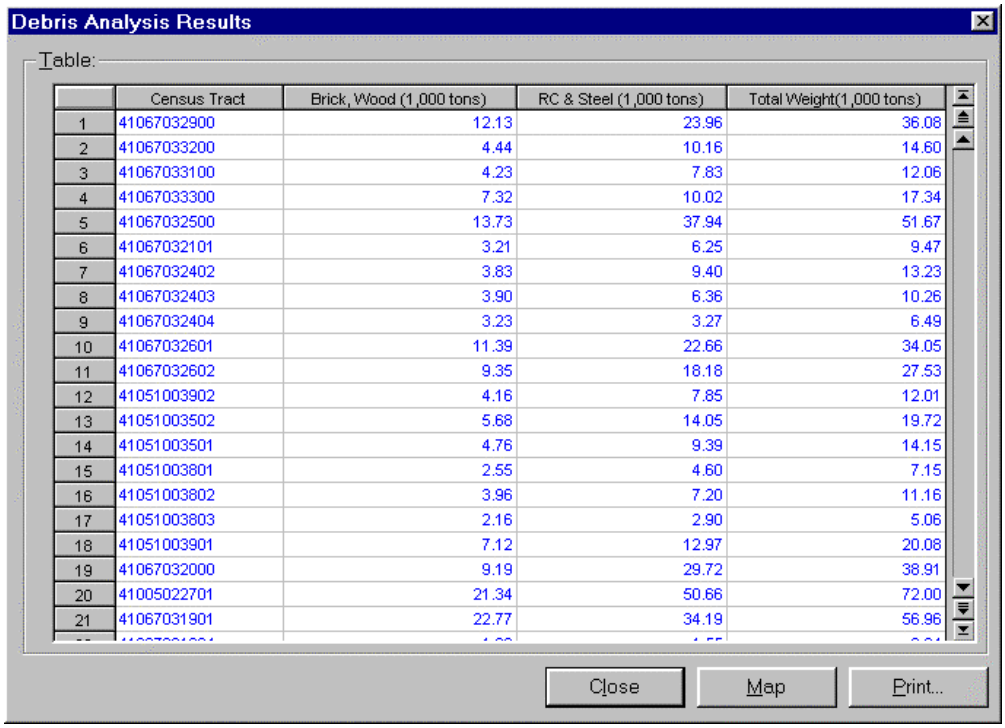
Figure 10.27 Map of percent of each census tract burned.

HAZUS provides information about the debris generated during the seismic event to enable users to prepare and to rapidly and efficiently manage debris removal and disposal. As shown in Table 10.11, two types of debris are identified: (1) reinforced concrete and steel that requires special equipment to break it up before it can be transported, and (2) brick, wood and other debris that can be loaded directly onto trucks with bulldozers. For each census tract, **HAZUS** determines the amount of debris of each type that is generated.

Table 10.11 Induced Physical Damage Module Outputs - Debris

Component	Description of Output	Measure
Brick, Wood & Others	a) **HAZUS** determines the expected amount of brick, wood, and other debris generated in each census tract of the study region.	a) Weight of Debris Generated
Reinforced Concrete & Steel	a) **HAZUS** determines the expected amount of reinforced concrete and steel debris generated in each census tract of the study region.	a) Weight of Debris Generated

In **HAZUS,** debris results will appear as a table, as shown in Figure 10.28, that can be printed to the screen or the printer. In addition, you will be able to map by census tract the weight of generated debris using the **Map** button, as shown in Figure 10.29.



	Census Tract	Brick, Wood (1,000 tons)	RC & Steel (1,000 tons)	Total Weight(1,000 tons)
1	41067032900	12.13	23.96	36.08
2	41067033200	4.44	10.16	14.60
3	41067033100	4.23	7.83	12.06
4	41067033300	7.32	10.02	17.34
5	41067032500	13.73	37.94	51.67
6	41067032101	3.21	6.25	9.47
7	41067032402	3.83	9.40	13.23
8	41067032403	3.90	6.36	10.26
9	41067032404	3.23	3.27	6.49
10	41067032601	11.39	22.66	34.05
11	41067032602	9.35	18.18	27.53
12	41051003902	4.16	7.85	12.01
13	41051003502	5.68	14.05	19.72
14	41051003501	4.76	9.39	14.15
15	41051003801	2.55	4.60	7.15
16	41051003802	3.96	7.20	11.16
17	41051003803	2.16	2.90	5.06
18	41051003901	7.12	12.97	20.08
19	41067032000	9.19	29.72	38.91
20	41005022701	21.34	50.66	72.00
21	41067031901	22.77	34.19	56.96

Figure 10.28 Output of the debris module in thousands of tons per census tract.

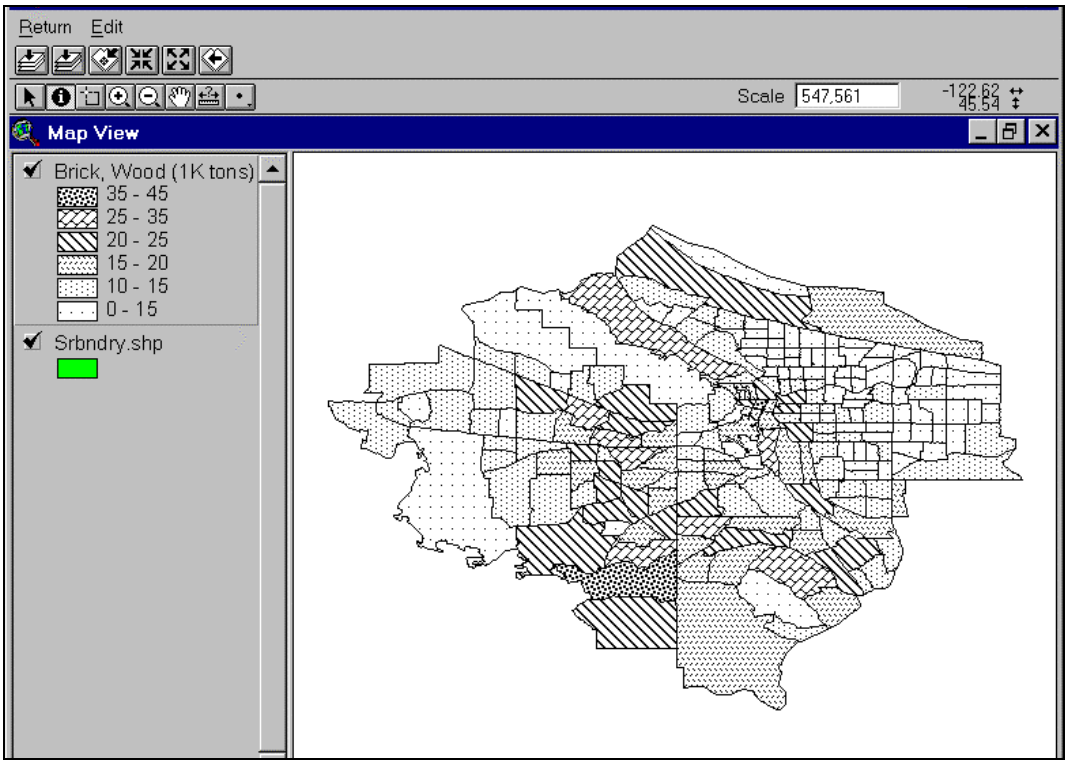


Figure 10.29 Weight of generated debris (brick, wood and other) by census tract.

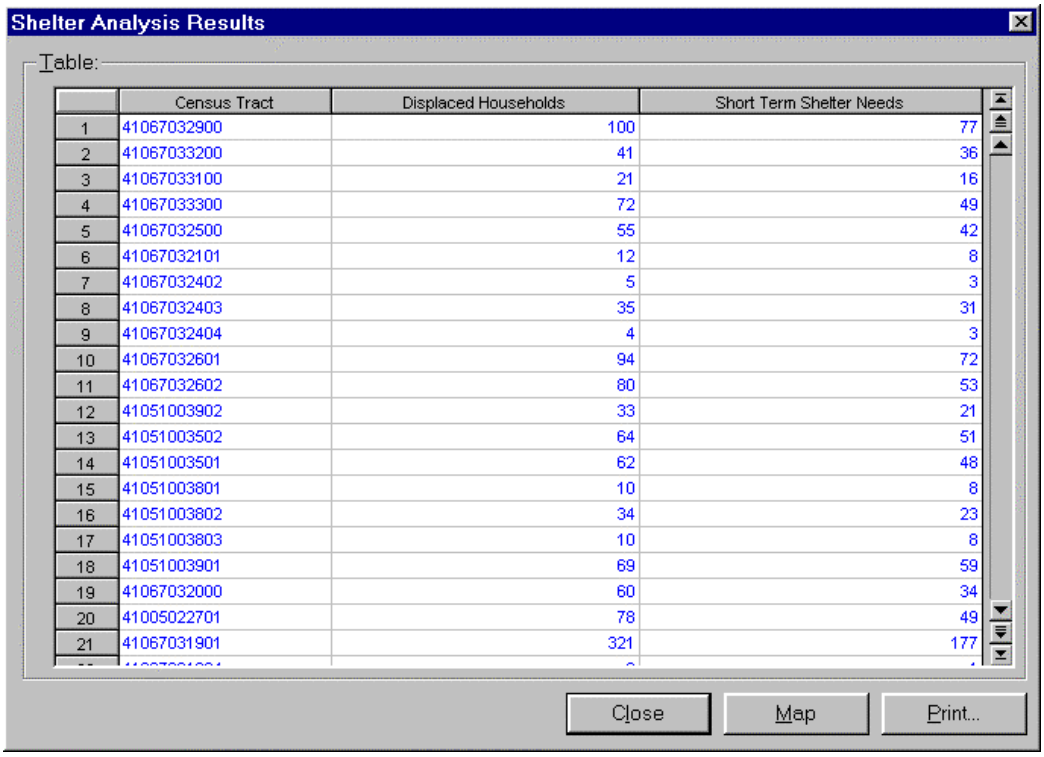
10.9 Direct Economic and Social Losses

HAZUS provides information concerning the estimated number of displaced households and persons requiring temporary shelter to enable the design of programs to temporarily shelter victims.

Table 10.11 Direct Economic and Social Losses Module Outputs - Shelter

Component	Description of Output	Measure
Displaced Households	a) **HAZUS** determines the expected number of displaced households by census tract in the study region.	a) Number of Displaced Households
Temporary Shelter	a) **HAZUS** determines the expected number of people requiring temporary shelter by census tract in the study region.	a) Number of People Requiring Temporary Shelter

The total number of displaced households for each census tract of the study region is one output of the shelter module. The number of displaced households is used to estimate the short-term shelter needs. Short-term shelter needs are reported in the number of people needing public shelter. The results, as displayed in Figure 10.30, are retrieved using the **Results|Shelter** menu. As with all results, these can be thematically mapped by highlighting a column and clicking on the **Map** button.



	Census Tract	Displaced Households	Short Term Shelter Needs
1	41067032900	100	77
2	41067033200	41	36
3	41067033100	21	16
4	41067033300	72	49
5	41067032500	55	42
6	41067032101	12	8
7	41067032402	5	3
8	41067032403	35	31
9	41067032404	4	3
10	41067032601	94	72
11	41067032602	80	53
12	41051003902	33	21
13	41051003502	64	51
14	41051003501	62	48
15	41051003801	10	8
16	41051003802	34	23
17	41051003803	10	8
18	41051003901	69	59
19	41067032000	60	34
20	41005022701	78	49
21	41067031901	321	177

Figure 10.30 Output of shelter module.

The output of the casualty module is summarized in Table 10.12.

Table 10.12 Direct Economic and Social Losses Module Outputs - Casualties

Component	Description of Output	Measure
Casualties	a) **HAZUS** determines the expected number of casualties for each casualty severity (treat/release, hospitalized, life-threatening, death) by census tract for the study region.	a) Number of casualties for each of the four severities

For each census tract, the following results (use **Results|Casualties** menu) are provided at three times of day (2 AM, 2 PM and 5 PM) by occupancy type or by building type.

- Residential casualties (severity 1, 2, 3 and 4)
- Commercial casualties (severity 1, 2, 3 and 4)
- Industrial casualties (severity 1, 2, 3 and 4)
- Commuting casualties (severity 1, 2, 3 and 4)
- Total casualties (severity 1, 2, 3 and 4)

As with the other output, highlighting the desired column and clicking on the Map button will map the results.

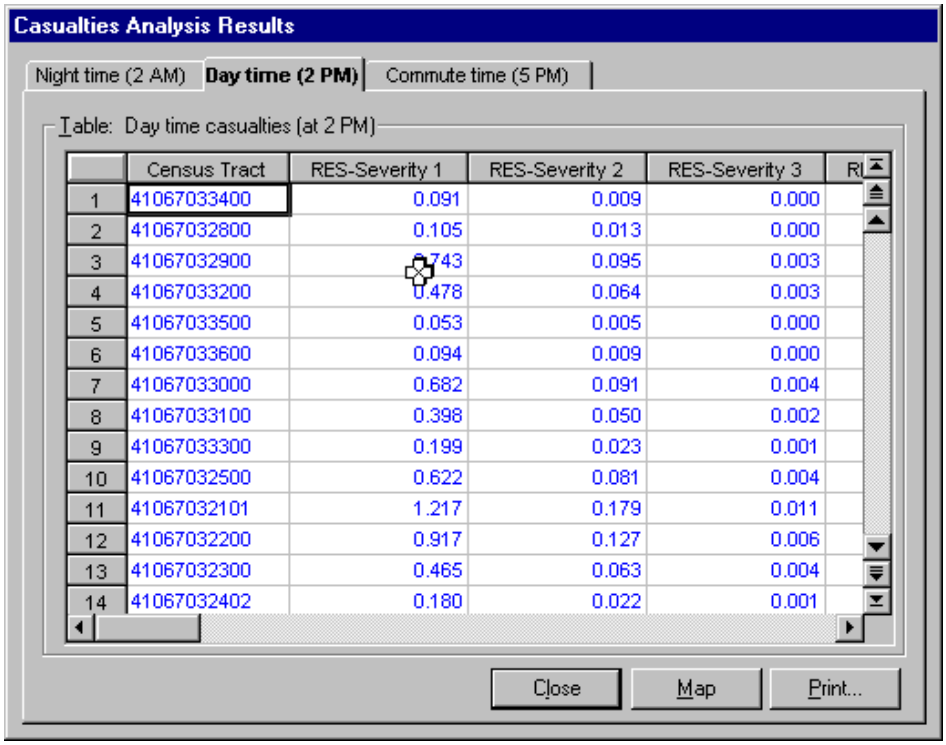


Figure 10.31 Output of casualty module showing residential casualties at 2 PM.

HAZUS provides economic loss information to enable users to motivate policy-makers to consider cost-benefit implication of mitigation activities. All default data for direct economic loss estimates are provided in 1994 dollars. You will need to convert 1994 dollars to those that are valid when you run your study. Losses for lifelines are reported separately from losses for buildings.

Table 10.13 Direct Economic and Social Losses Module Outputs - Direct Economic Loss - Buildings

Component	Description of Output	Measure
Repair and Replacement Costs	a) **HAZUS** determines the expected dollar loss due to the repair and replacement of the general building stock by census tract for the study region.	a) Dollar Loss
Contents Damage	a) **HAZUS** determines the expected dollar loss due to contents damage by census tract for the study region.	a) Dollar Loss
Business Inventory Damage	a) **HAZUS** determines the expected dollar loss due to business inventory damage by census tract for the study region.	a) Dollar Loss
Relocation Costs	a) **HAZUS** determines the expected dollar loss due to business relocation by census tract for the study region.	a) Dollar Loss
Capital-related Income Loss	a) **HAZUS** determines the expected business income loss by census tract for the study region.	a) Dollar Loss
Wage Loss	a) **HAZUS** determines the expected wage loss by census tract for the study region.	a) Dollar Loss
Rental Loss	a) **HAZUS** determines the expected dollar loss due to the repair and replacement of buildings by census tract for the study region.	a) Dollar Loss

Building loss estimates can be viewed by clicking on the **Results|Buildings Economic Loss** menu. Building losses are summarized in terms of the seven General Occupancy classes (Residential, Commercial, Industrial, Agriculture, Religious, Government and Education), or in terms of the 28 Specific Occupancy Classes. As can be seen in Figure 10.32, the total direct economic losses for each census tract are reported. The total losses include structural and non-structural repair, contents loss, relocation costs, proprietor's income loss and rental loss.

Losses also can be reported by type. The types reported are structural and non-structural repair, total building costs (the sum of structural and non-structural), contents loss, relocation costs, proprietor's income loss and rental loss. These losses are reported by census tract for each of the seven general occupancy classes as shown in Figure 10.33.

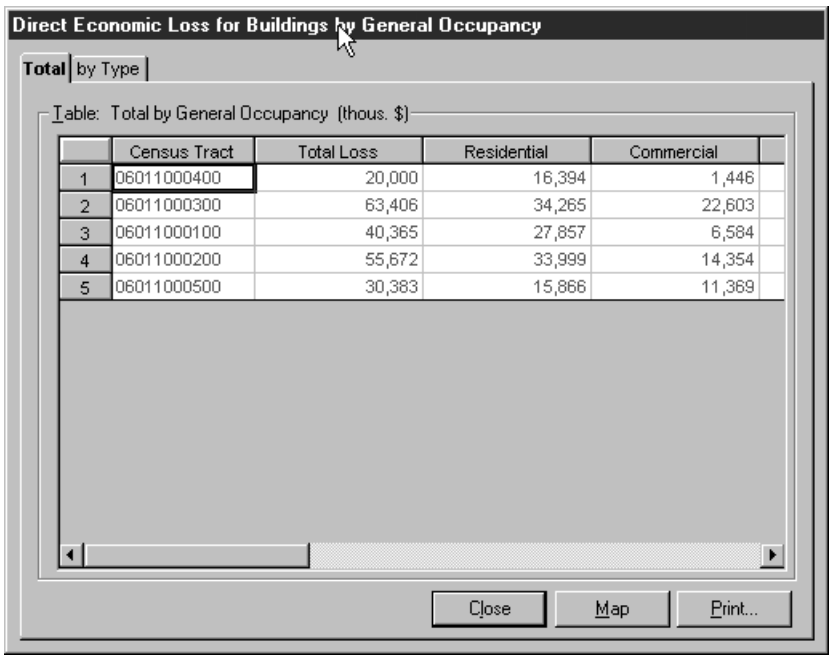


Figure 10.32 Total building losses reported by general occupancy class

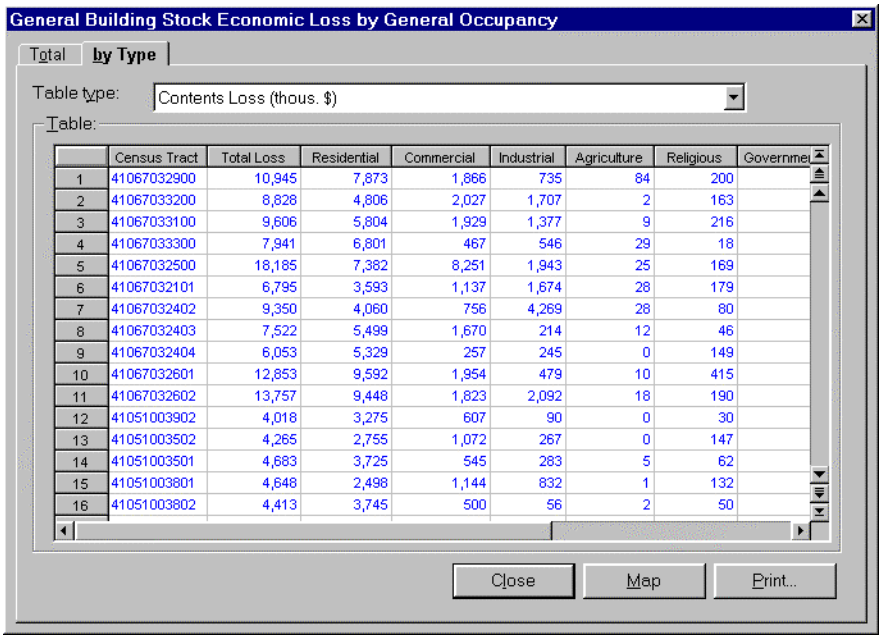


Figure 10.33 Types of building losses reported by general occupancy class

The total loss of each type for all economic sectors can be viewed using the window shown in Figure 10.34. This window differs from that shown in Figure 10.33 in that, for example, the total cost of structural damage as reported in Figure 10.34 is the sum of the contents damage for all of the seven general occupancies shown in Figure 10.33.

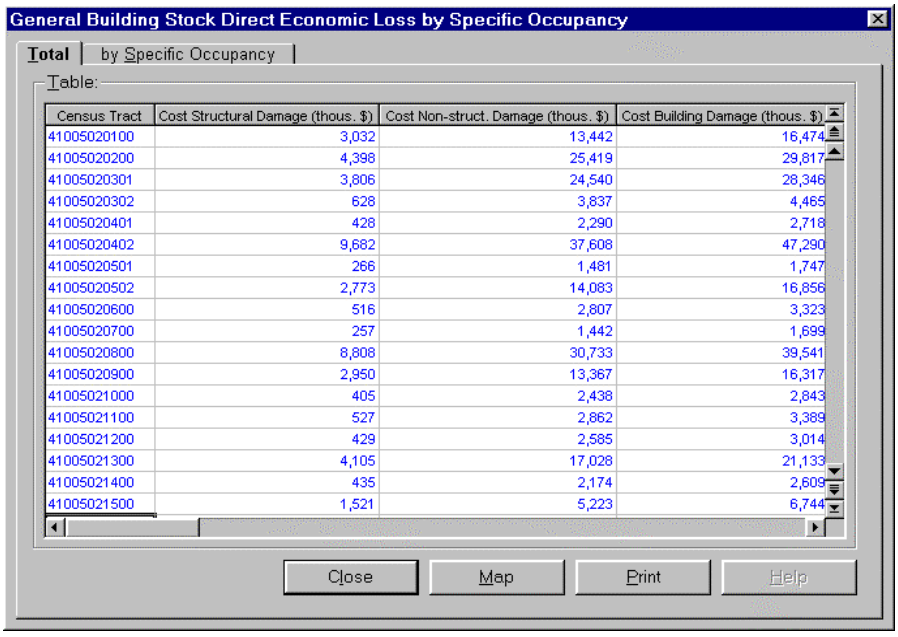


Figure 10.34 Types of building losses reported by census tract.

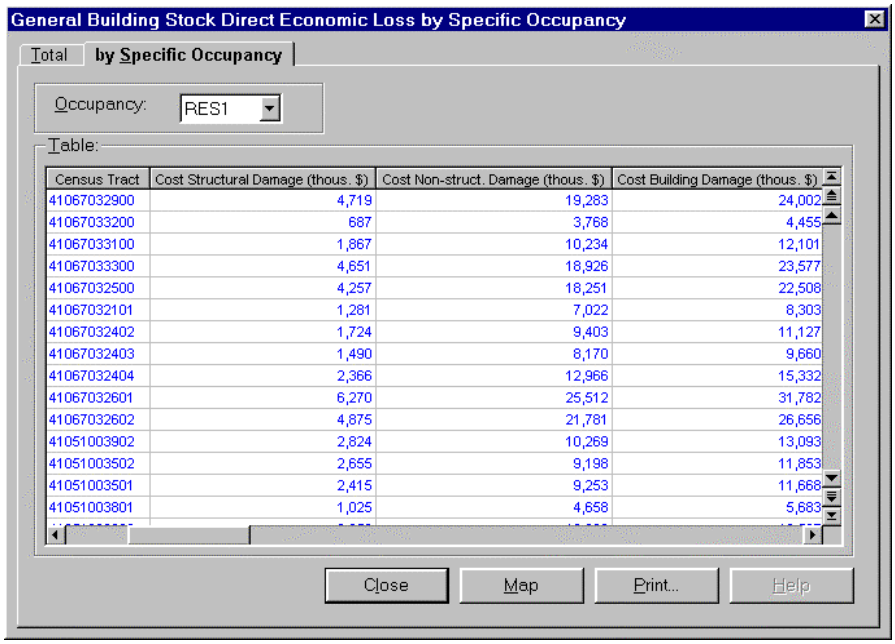


Figure 10.35 Types of building losses reported by specific occupancy

Finally, losses can be reported for each of the 28 specific occupancy classes for each census tract as shown in Figure 10.35.

The loss estimates for lifeline systems are summarized in Table 10.14. These are accessed through the **Results|Lifelines Economic Loss** menu.

Table 10.14 Direct economic and social losses module outputs - direct economic loss - lifelines

Component	Description of Output	Measure
Repair and Replacement Costs	a) The methodology determines the expected dollar loss due to the repair and replacement of lifelines components.	a) Dollar Loss

Figure 10.36 shows an example of a results window for transportation systems. Losses are reported for each component of the system, for example, in this window, losses are reported for each highway bridge. You can create similar reports for each type of component and each type of lifeline by clicking on the tabs at the top of Figure 10.36 and using the list box next to the label "Table Type". The results in Figures 10.32 through 10.36 can be mapped by clicking on the **Map** button.

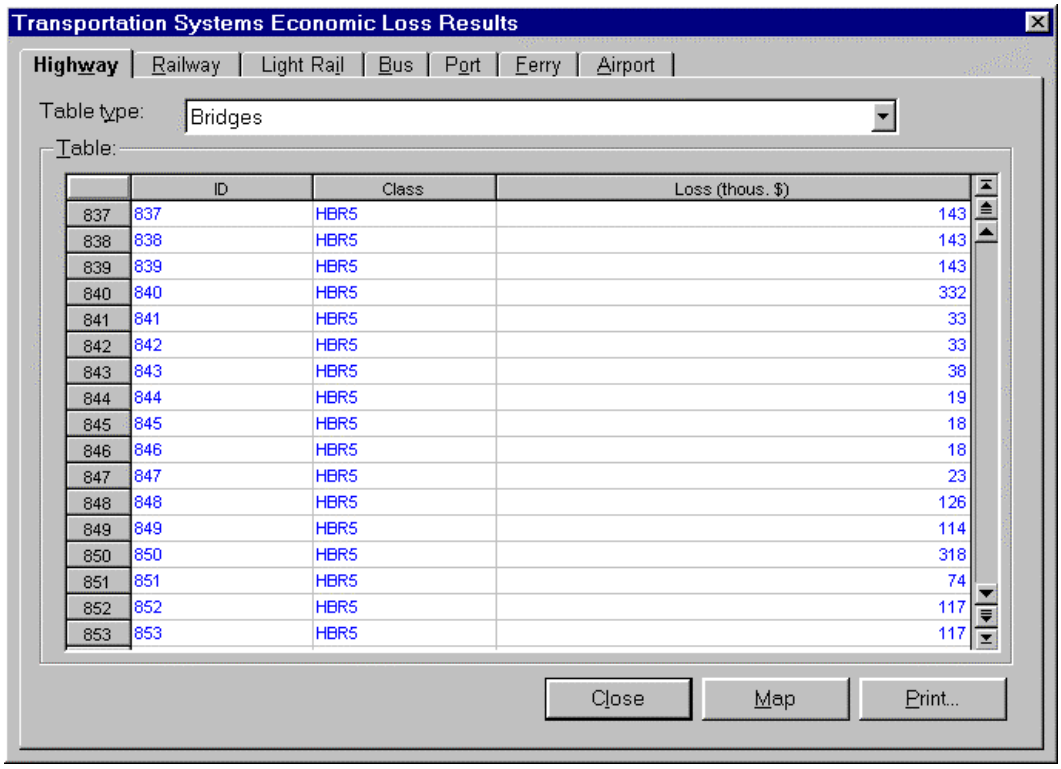


Figure 10.36 Direct economic losses to lifeline components

10.10 Indirect Economic Impacts

HAZUS provides information concerning the indirect economic effects of the scenario event to enable financial institutions and government planners to anticipate losses and develop programs to compensate for them. The indirect economic impact information also enables users to motivate policy-makers to consider cost-benefit implications of mitigation activities.

Table 10.15 Indirect economic impacts module outputs

Component	Description of Output	Measure
Economic Output	a) Indirect output loss as a percentage of original output	Percentage
Employment	a) Indirect employment loss as a percentage of original employment	Percentage
Income	a) Indirect income loss as a percentage of original income	Percentage

10.11 Summary Reports

The options to view summaries of the outputs of each of the **HAZUS** modules are: Inventory, Building Damage, Lifeline Damage, Induced Damage and Losses as shown in the Figure 10.37. You can pick the summary report from any of the windows below and click on the **View** button to generate the report. Sample summary reports of building damage by general occupancy and building stock exposure by building type are shown in Figures 10.38 and 10.39. Additional information in these reports can be viewed by scrolling to the right. Clicking on the print button can print reports.

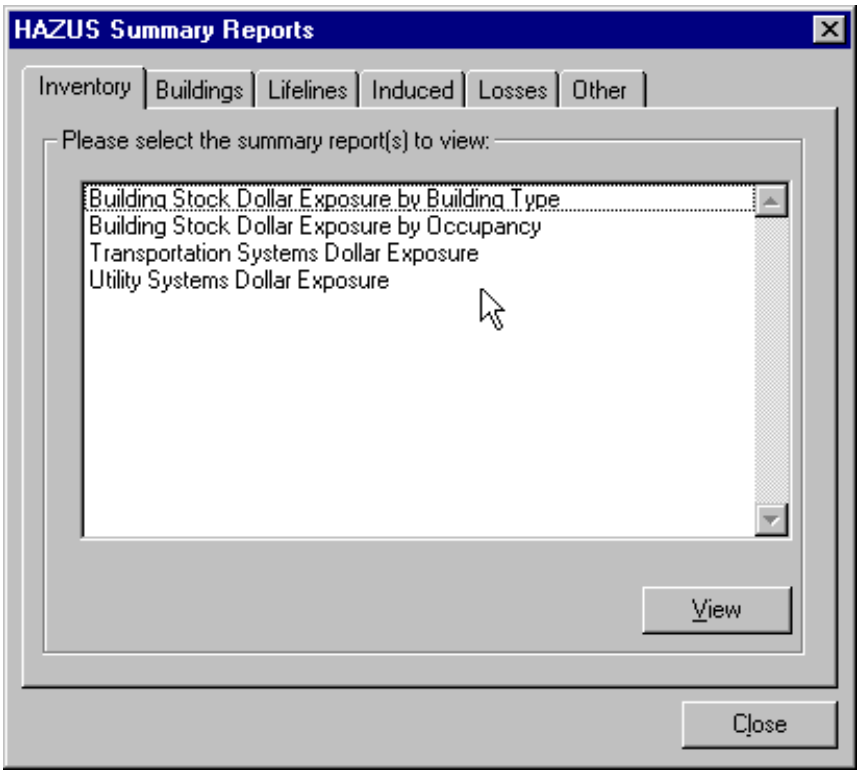


Figure 10.37 Summary report selection window for inventory summary report.

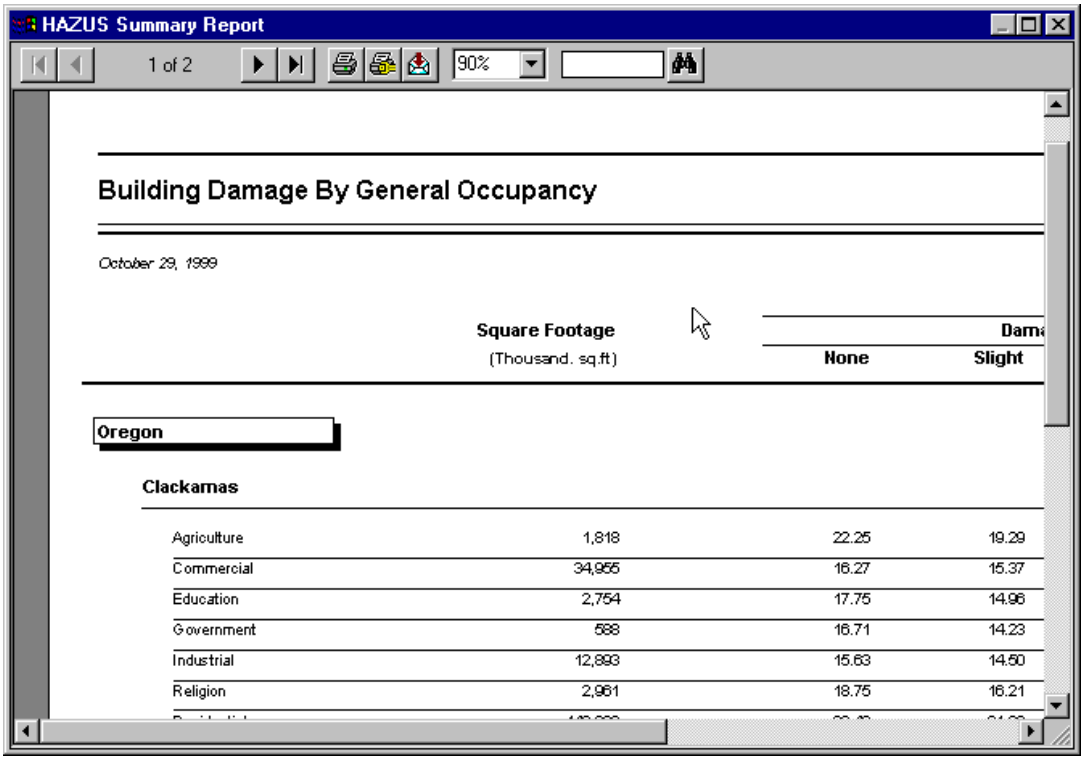


Figure 10.38 Sample summary report of building damage by general occupancy.

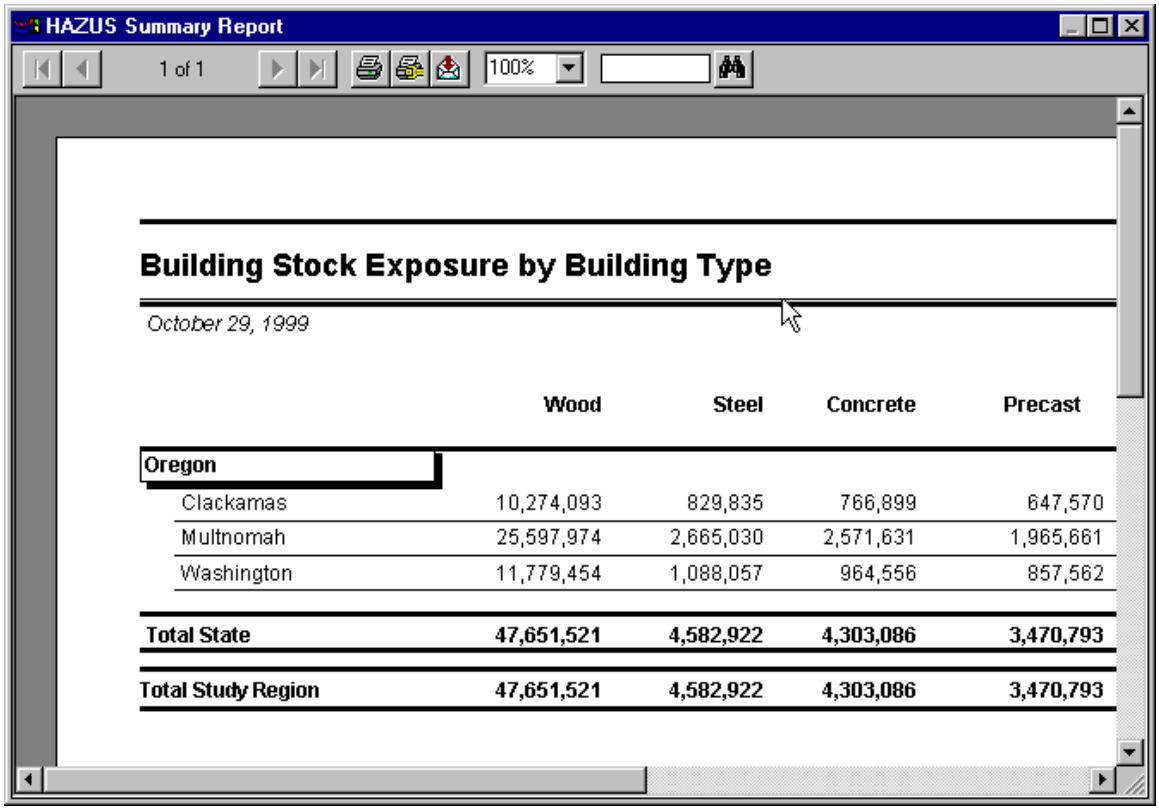


Figure 10.39 Sample summary report of building stock exposure by building type.

The 20 page **Global Summary Report** is a comprehensive standardized summary report that provides inventory, hazard and analysis results related to the scenario event. Selecting the **Other** tab as shown in Figure 10.40 will access the window that contains the **Global Summary Report**.

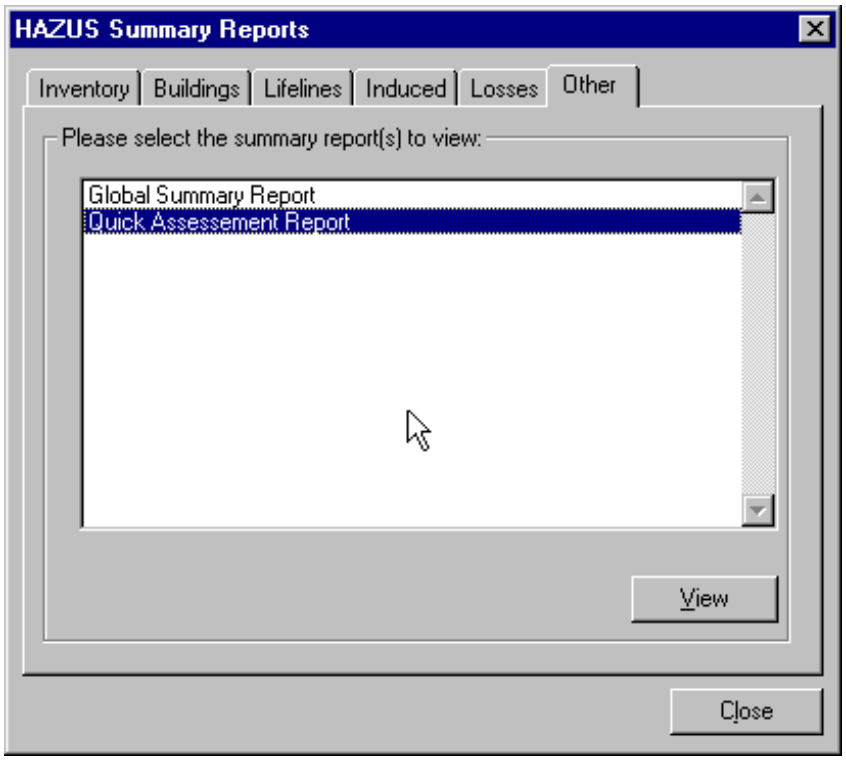


Figure 10.40 The Global Summary report option

The Global Summary Report is organized as follows:

1. **General Description of the Region**
2. **Building and Lifeline Inventory**
   - **2.A Building Inventory**
   - **2.B Critical Facility Inventory**
   - **2.C Transportation and Utility Lifeline Inventory**
3. **Earthquake Scenario Parameters**
4. **Direct Earthquake Damage**
   - **4.A Buildings Damage**
   - **4.B Critical Facilities Damage**
   - **4.C Transportation and Utility Lifeline Damage**
5. **Induced Earthquake Damage**
   - **5.A Fire Following Earthquake**
   - **5.B Debris Generation**
6. **Social Impact**
   - **6.A Shelter Requirements**
   - **6.B Casualties**
7. **Economic Loss**
   - **7.A Building Losses**
   - **7.B Transportation and Utility Lifeline Losses**
   - **7.C Long-term Indirect Economic Impacts**

10.12 Ground-Truthing the Results

The analysis results obtained from **HAZUS** are the best estimates given the current state-of-the-art earthquake engineering algorithms, but when a real earthquake event occurs, the damage observed on the ground ***is*** the absolute.

Through the ground-truthing feature, **HAZUS** allows the user to feed it the real observed data so that analysis results can get refined. For example, **HAZUS** uses the damage to say the medical care facilities to calculate their functionality, but if the damage values can be updated with real observed data, then **HAZUS** can use those new values to refine the functionality analysis for said medical care facilities.

To use the ground-truthing feature, follow the steps below:

1. Run an analysis including all of the modules
2. By default, ground-truthing is off. To find out the current setting, select the **Analysis** menu option as showing in Figure 10.41. The ground-truthing option will either show as **Ground Truthing Off** or **Ground Truthing On.** Also, when ground truthing is off, all of the results tables are non-editable (they show up in blue.)
   The ground truthing menu option is a toggle, so if the option is off, selecting it will toggle the ground truthing to *on.*

Figure 10.41. The Ground Truthing option

3. Select the results table which you need to edit/ground truth
4. Right-click the table to invoke the data management pop-up menu. When ground truthing is on, the option **Edit results** becomes enabled and can be selected as shown in Figure below.

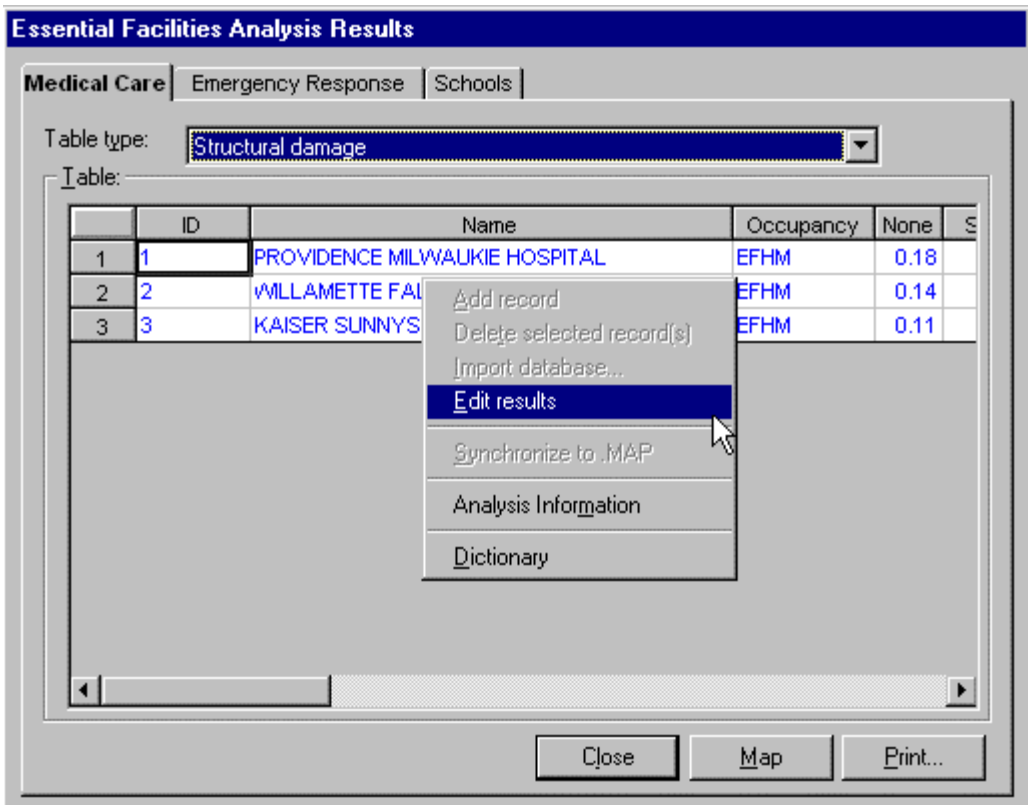


Figure 10.42 Ground Truthing option

5. Click on **Edit results** then all the result cells become editable (showing in black). Edit the appropriate values as needed. When done, click **Close** and say **yes** to the **Data table changed. Save to file?**

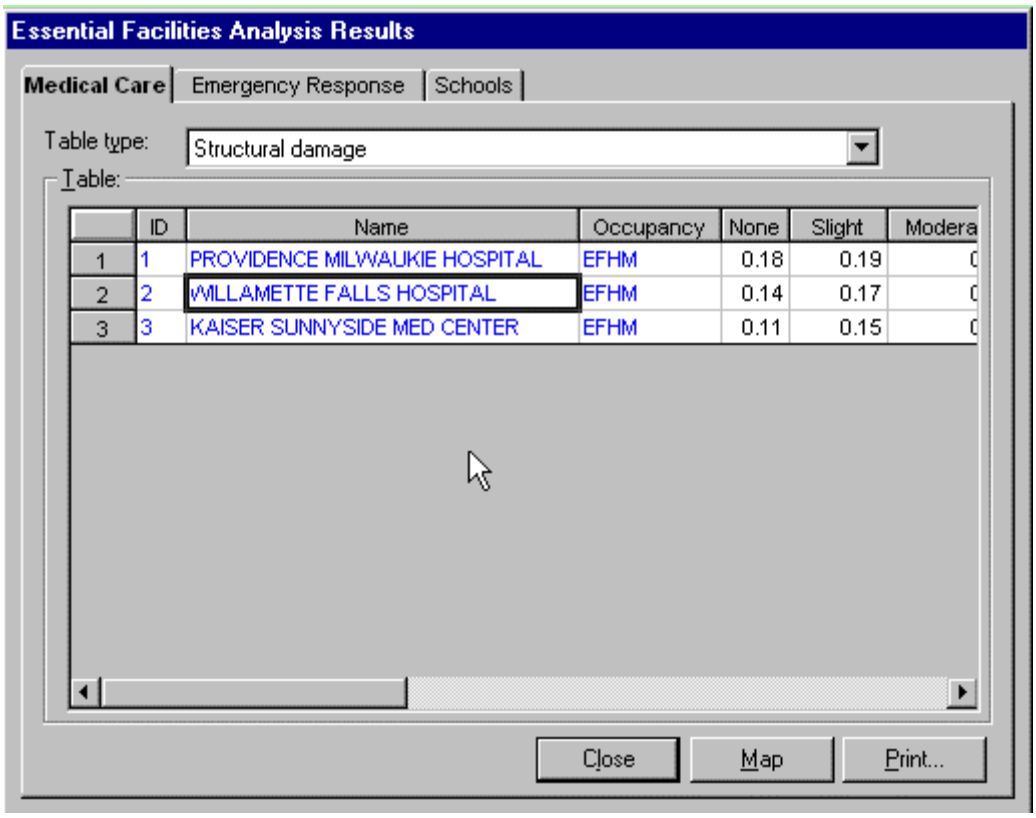


Figure 10.44 Results table in edit mode

6. Re-run the analysis on the dependant modules (or if in doubt, run all modules). **HAZUS** will use the entered values when needed. In the example above, if the value for "Slight" is updated for the hospital ID 2, then this value and only this value will be used. All the other values will be calculated by **HAZUS** as before.

Steps 3 through 6 can be repeated as many times as needed. ***The ground truthing mode stays in effect until it is turned off explicitly.*** This allows the refinement of the results as more observed data is fed into the **HAZUS**.

Note:

When the ground truthing option is turned off, all of the entered values are *discarded*.